

JPL 2017 Phase I STTRs

Company	Research Title and Subtopic
Applied Research, LLC	Fusion of THEMIS and TES for Accurate Mars Surface Characterization (T8.01-9908)
ASTER Labs, Inc.	Reinforcement Learning For Coordination And Control of Swarming Satellites (T4.03-9857)
Creare, LLC	Accurate, Miniature Attitude Determination System (T4.03-9792)
Honeybee Robotics, Ltd.	Instrumented Bit for In-Situ Spectroscopy (IBISS) (T8.01-9875)
Scientific Systems Company, Inc.	DISCUS: Distributed Intelligent Swarm Control & Utilization System (T4.03-9829)

JPL 2017 Phase I SBIRs

Company	Research Title and Subtopic
AI Biosciences, Inc.	A 3D Printer Enabled, High Performing, Microgravity Compatible, and Versatile Sample Preparation Platform (H3.02-9356)
Air Squared, Inc.	High Capacity Multi-Stage Scroll Compressor for Mars Atmosphere Acquisition (H1.01-9317)
Alphacore, Inc.	Rad-Hard LDO (S4.04-8643)
Antara Teknik, LLC	Efficient and Secure Network and Application Communications for Small Spacecraft (Z8.02-9571)
Ashwin-Ushas Corp, Inc.	Unique, Voltammetric Electrochemical Sensors for Organic Contaminants, with Excellent Discrimination, Based on Conducting Polymer-, Aptamer- and Other-Functionalized Sensing Electrodes (S4.05-8282)

Company	Research Title and Subtopic
Atlas Scientific	Regenerators for 10 Kelvin Cryocoolers (S1.09-9887)
Busek Company, Inc.	Ultra-Compact Center-Mounted Hollow Cathodes for Hall Effect Thrusters (S3.02-9225)
Chronos Technology (Div. of FMI, Inc.)	+500C Hi-Rel Rad Hard, Rugged Modulator (S4.04-8391)
Cornerstone Research Group, Inc.	Ultra-Lightweight MG Syntactic for Insulation in Extreme Environments (Z2.01-9459)
Creare, LLC	A Two-Phase Pumped Loop Evaporator with Adaptive Flow Distribution for Large Area Cooling (S3.06-8949)
CU Aerospace, LLC	Fiber Fed Advanced Pulsed Plasma Thruster (APPT) (Z8.01-9758)
Custom MMIC Design Services, Inc.	GaN MMIC Ka-Band Power Amplifier (H9.04-8557)
ExoTerra Resource, LLC	High Power Radiation Tolerant CubeSat Power System (Z8.03-8424)
Faraday Technology, Inc.	Manufacturing Decision Tree Model Optimization for Finishing Additive Manufactured Components (Z3.02-9720)
Fibertek, Inc.	High Power (50W) WDM Space Lasercom 1.5um Fiber Laser Transmitter (H9.01-8624)
Honeybee Robotics, Ltd.	SLUSH: Europa Hybrid Deep Drill (S4.02-8511)
Honeybee Robotics, Ltd.	Europa Drum Sampler (EDuS) (S4.02-9693)
Honeybee Robotics, Ltd.	High Temperature Stirling Cooler (S4.04-8372)
Integra Technologies, Inc.	A High Efficiency 400W GaN Amplifier for X-Band Radar Remote Sensing Using >50 VDC FETs (S1.02-8426)

Company	Research Title and Subtopic
Intelligent Optical Systems, Inc.	Luminescent Sensors for Ocean Water Monitoring (S1.08-8821)
Irvine Sensors Corporation	FLASHRAD: A 3D Rad Hard Memory Module For High Performance Space Computers (Z6.01-8732)
Leiden Measurement Technology, LLC	WOLFEChip: Wholly-Integrated Optofluidic Laser-Induced Fluorescence Electrophoresis Chip (S1.11-8595)
LongWave Photonics, LLC	Tunable, High-Power Terahertz Quantum Cascade Laser Local Oscillator (S1.04-9669)
Luna Innovations, Inc.	Extended Length Marsupial Rover Sensing Tether (S4.02-9202)
MaXentric Technologies, LLC	Optically Assisted Analog-to-Digital Converter for Next Generation "Software Defined" Radios (H9.04-8956)
Microscale, Inc.	Next-Generation Deformable Mirrors for Astronomical Coronagraphy by Utilizing PMN-PT Single Crystal Stack Actuators in integration with Driver ASIC (S2.01-9655)
MMA Design, LLC	Deployable Ka/W Dual Band Cylindrical Parabolic Antenna Including Feed Support Structure (S1.02-9973)
Nanohmics, Inc.	Proximity Glare Suppression for Astronomical Coronagraphy (S2.01-8536)
Nova Photonics, Inc.	Coded Aperture Techniques for High-Throughput Imaging Spectroscopy (S1.07-8853)
NuCrypt, LLC	Improved Microwave Photonic Links via Receive-Side Nonlinear Signal Processing (S1.02-9156)
OEwaves, Inc.	Optical Flywheel for Yb+ Ion Clock (S1.10-8993)
Omega Optical, Inc.	Ultra-Narrow Bandpass Filters for Long Range Optical Telecommunications at 1064nm and 1550nm (H9.01-8737)

Company	Research Title and Subtopic
Optical Engines, Inc.	Kilowatt Level Uplinks for Deep Space Optical Communications (H9.01-8808)
Pacific Microchip Corporation	Correlation Radiometer ASIC (S1.03-9385)
Pacific Microchip Corporation	A Low Power Rad-Hard ADC for the KID Readout Electronics (S1.04-8763)
Photonic Cleaning Technologies, LLC	Polymer Coating-Based Contaminant Control/Elimination for Exo-S Starshade Probe (S2.01-9936)
Physical Sciences, Inc.	Antimicrobial Coating for Metallic Surfaces (S4.05-9760)
Redondo Optics, Inc.	Weaved Distributed Plastic Optical Fiber Sensor (DIFOS) SHM system (Z7.01-8404)
Remote Sensing Solutions, Inc.	An Enhanced Modular Terminal Descent Sensor for Landing on Planetary Bodies (S4.01-8340)
South 8 Technologies, Inc.	Liquefied Gas Catholytes for Ultra-Low Temperature Lithium Primary Batteries (S3.03-9828)
Supercool Metals, LLC	Thermoplastic Forming of Bulk Metallic Glasses for Precision Robotics Components (Z3.02-8909)
TDA Research, Inc.	Thermal Insulator for a Venus Lander (Z2.01-9104)
Tendeg, LLC	Enabling Larger Deployable Ka-Band Antenna Apertures with Novel Rib (S1.02-9250)
Tendeg, LLC	Redundant StarShade Truss Deployment Motor/Cable Assembly (S2.02-8520)
Troxel Aerospace Industries, Inc.	Robust Multicore Middleware (Z6.01-8473)
Ultramet	Advanced Ignition System for Hybrid Rockets for Sample Return Missions (S4.03-8399)
Wecoso, LLC	SmallSat Stirling Cryocooler for Earth Science and Interplanetary Exploration (S1.09-9809)
ZeCoat Corporation	Battery-Powered Process for Coating Telescope Mirrors in Space (S2.04-9520)

Company	Research Title and Subtopic
Boston Micromachines Corporation	Technology Development for High-Actuator-Count MEMS DM Systems (S2.01-9865)
Blue Sun Enterprise, Inc.	AutoNav Mark 4: Autonomous Navigation Software (S3.04-8513)

NASA SBIR/STTR Technologies

T8.01-9908 - Fusion of THEMIS and TES for Accurate Mars Surface Characterization



PI: Chiman Kwan

Applied Research, LLC - Rockville, MD

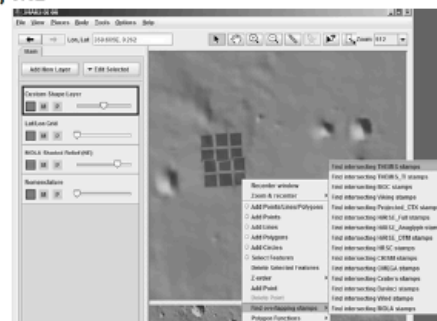
Identification and Significance of Innovation

Recently, NASA has expressed strong interest in improving surface characterization of Mars using orbital imagers. Thermal Emission Imaging System (THEMIS) and Thermal Emission Spectrometer (TES) are orbital multispectral imagers of Mars. THEMIS has 10 spectral bands in the 6-13 micrometers region and a spatial resolution of 100 m. TES has 143 spectral bands in the 5-50 micrometers range, but with low spatial resolution of 3x3 km. Although both have been used to map out the surface composition of Mars, there are some limitations. First, THEMIS has low spectral resolution that may not provide accurate surface characterization. Second, TES has low spatial resolution that cannot provide fine spatial details of surface characteristics. Each TES pixel contains about 900 THEMIS pixels. It is very challenging to fuse the two data sets. We propose a novel and accurate framework that can deal with the above challenge. The framework is based on the latest development in image fusion, anomaly detection, pixel classification using hyperspectral images, and concentration estimation.

Estimated TRL at beginning and end of contract: (Begin: 1 End: 3)

Technical Objectives and Work Plan

The goal of our Phase 1 effort is to develop an accurate software that uses THEMIS and TES for Mars surface characterization from orbit. We will demonstrate the feasibility of the system using actual data. In Phase 2, we will develop a software prototype that can achieve accurate surface characterization from orbit and has comparable or close performance as ground based instruments. We will also integrate the tool with JMARS. Extensive experiments will be performed to demonstrate the prototype for real operations.



Spatial resolution difference between THEMIS and TES. Background shows one band of THEMIS. Each dark square shows a single TES pixel. Fusion of THEMIS and TES will enable more accurate surface characterization from orbit.

NASA Applications

In addition to Mars application, our approach will be applicable to fuse high resolution Worldview images with MODIS, AVHRR, and HyspIRI images to yield high resolution in both spatial and spectral domains. Consequently, many applications, including urban monitoring, vegetation monitoring, fire and flood damage assessment, etc., will benefit from the high spatial and high spectral resolution images.

Non-NASA Applications

Our proposed surface characterization system can be used for military surveillance and reconnaissance and civilian applications such as border patrol, coastal monitoring, vegetation monitoring, urban development monitoring, etc. The combined market can be over 5 million dollars over the next decade. The market size is based on an estimated of users of 5,000 and a unit price of \$1,000 per software.

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

T4.03-9857 - Reinforcement Learning For Coordination And Control of Swarming Satellites



PI: Suneel Sheikh
ASTER Labs, Inc. - Shoreview, MN

Identification and Significance of Innovation

This Phase I program will investigate a new approach for achieving efficient, near-optimal control of swarm formations of spacecraft with direct application to communication-less coordination. These objectives are achieved by employing Reinforcement Learning (RL) theory to solve the optimal control problem. Each individual agent in the Multi-Agent System learns behaviors that govern local coupling in a swarm using global centralized solutions. The proposed innovation will develop and demonstrate a decentralized Reinforcement Learning solution to optimal control of space vehicles. It will develop novel swarm decentralized control approaches that can mitigate limitations in sensor, communication, and actuation capabilities in large homogeneous space vehicle swarms. Phase I development will directly support identified NASA roadmap needs for relative formation control, and algorithmic approaches for large spacecraft systems and ground planetary exploration vehicle swarms.

Estimated TRL at beginning and end of contract: (Begin: 2 End: 3)

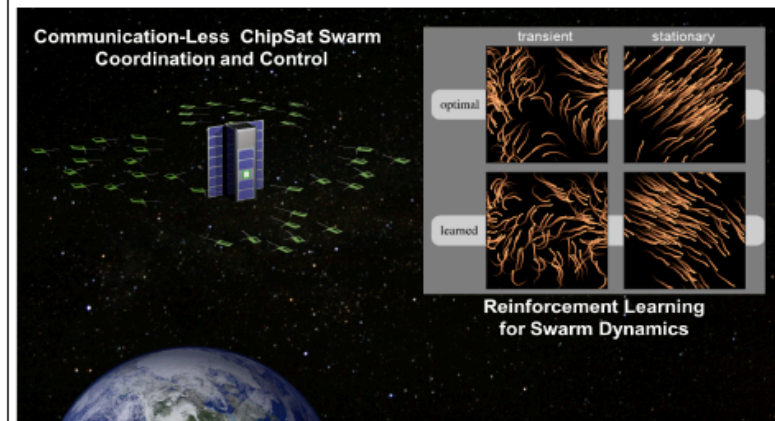
Technical Objectives and Work Plan

Technical Objectives:

1. Develop full centralized optimal control solution for large swarm for training efficient RL approaches
2. Develop Inverse RL approach for determining local decentralized control strategies
3. Develop model free reinforcement learning approaches that map from observations to actions
4. Develop SWRL approach for planetary rover swarms
5. Develop Human-Swarm Interface through online RL
6. Develop custom Human provided reward models for RL

Work Plan:

- Task 1: Approximate Optimal Control for Large Swarm via Reinforcement Learning
Task 2: Communication-Less Swarm Coordination
Task 3: Human-Swarm Interactions via Supervised Reinforcement Learning
Task 4: Program Management



NASA Applications

- Autonomous planetary rover swarms
- Asteroid and comet exploration
- Earth orbiting swarms
- Formation flying navigation capabilities

Non-NASA Applications

- Search and rescue unmanned aerial system coordination and automation
- DoD robotic vehicle unit coordination
- Reduced communication requirements for land, sea, and air vehicle sets
- Formation control for commercial inter-satellite telecom networks

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

T4.03-9792 - Accurate, Miniature Attitude Determination System

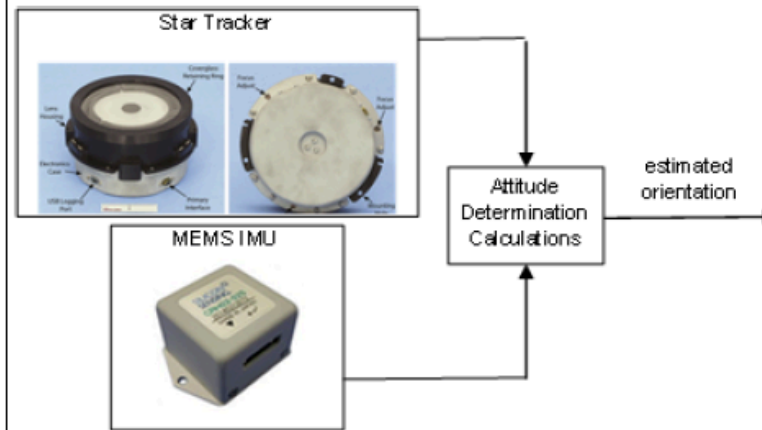


PI: Brynmor Davis
Creare, LLC - Hanover, NH

Identification and Significance of Innovation

The overall goal of this project is to design, develop, and demonstrate in a flight test, a miniature, accurate, attitude determination system (ADS) for use on small satellites. The ADS combines a previously developed compact star tracker with arc second attitude accuracy with a MEMS IMU that has near laser gyro accuracy. The ADS will fit the CubeSat form factor. The ADS addresses the needs of small (1U to 3U) CubeSats as well as larger (6U to 27U) "small" satellites.

Creare will combine its unique technology with the unique testing environments that the University of Hawaii Spaceflight Laboratory has access to, including laboratory, field, and space missions.



Estimated TRL at beginning and end of contract: (Begin: 5 End: 6)

Technical Objectives and Work Plan

Technical Objectives

The Phase I technical objectives are to:

1. Understand the science driven requirements for a small satellite ADS.
2. To verify that our ADS technology meets the requirements with laboratory and field testing.
3. To investigate the ADS design space for various small satellite missions.
4. To design a space-qualifiable ADS that will be built and tested on a space mission during Phase II.

Work Plan

- Task 1. Design and Assemble the ADS
- Task 2. Implement the ADS Algorithms
- Task 3. Phase I ADS Testing
- Task 4. Develop Phase II Mission Design
- Task 5. Manage and Report

NASA Applications

NASA is interested in reducing the mass and cost while maximizing the scientific return for future NASA missions. Small satellites are an excellent alternative for achieving these goals. One of the key enabling technologies for small satellites is a miniature, accurate, attitude determination system. Our miniature high-accuracy attitude determination system promises to meet the needs of small satellites for high-accuracy attitude control and formation flying missions.

Non-NASA Applications

Past technical advances in small satellites have opened up new markets for small satellites. Markets include military science and technology; intelligence, surveillance, and reconnaissance; remote site communications; high-resolution Earth observations; and Landsat-class environmental monitoring. Our high-accuracy attitude determination system will enable higher performance for many applications.

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

T8.01-9875 - Instrumented Bit for In-Situ Spectroscopy (IBISS)

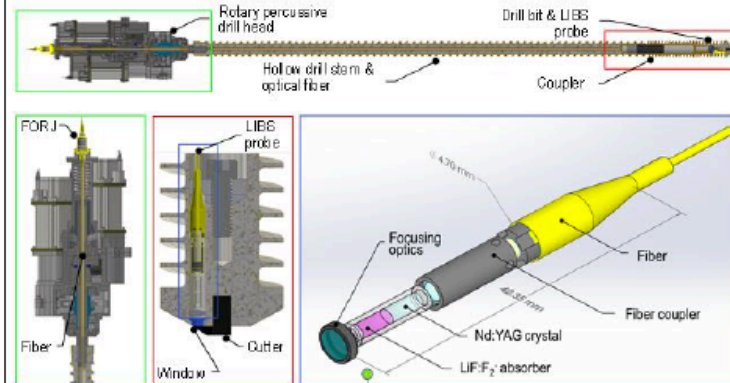


PI: Pablo Sobron

Honeybee Robotics, Ltd. - Brooklyn, NY

Identification and Significance of Innovation

Developing instruments for the in-situ characterization of subsurface environments is the most scientifically sound, and the most technologically feasible strategy to meet key science goals of the Decadal Survey. We propose to build and test IBISS, a novel system for in-situ, rapid analyses of planetary subsurface materials. IBISS integrates, for the first time, an innovative LIBS (laser-induced breakdown spectroscopy) probe with a drill bit to deliver depth-resolved downhole chemical and mineralogical identification and quantitation of subsurface materials while drilling. With IBISS, we bring a very powerful instrument to the subsurface, as opposed to bringing subsurface samples to an instrument.



Estimated TRL at beginning and end of contract: (Begin: 2 End: 4)

Technical Objectives and Work Plan

The goal of this Phase I project is to develop and integrate key subsystems of IBISS and critically evaluate its performance using standards. We will demonstrate the feasibility of IBISS to perform LIBS analysis during drilling in planetary simulants.

Phase I Technical Objectives are:

1. Design and assemble an IBISS breadboard system (Mk 1) and validate the optical circuit.
2. Design and assemble an IBISS miniaturized system (Mk 2), integrate it with the drill bit, and bench test it.

We will carry out these two objectives in succession over a 12-month period.

NASA Applications

NASA applications: a) Landed exploration missions to Ocean worlds, Venus, Moon, Mars, Europa, Titan, comets, and asteroids; b) sample return missions to Moon, Mars, comets and asteroids; c) autonomous in-situ resource utilization (ISRU) devices for robotic and human missions.

Non-NASA Applications

Non-NASA applications: IBISS will enable interdisciplinary advances in all fields that require rapid, in-situ characterization of subsurface materials, including Earth and environmental sciences; geological prospecting; environmental monitoring/assessment; agricultural soil quality monitoring; oil & gas exploration and development; homeland security initiatives

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

T4.03-9829 - DISCUS: Distributed Intelligent Swarm Control & Utilization System



PI: Jovan Boskovic

Scientific Systems Company, Inc. - Woburn, MA

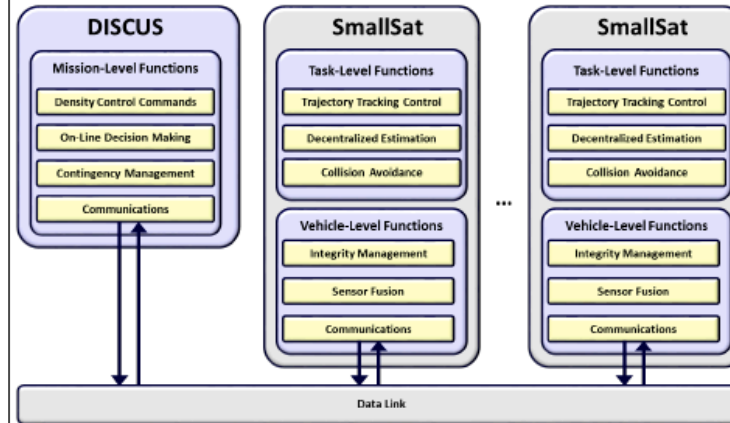
Identification and Significance of Innovation

Flight of swarms of hundreds to thousands small-scale satellites presents a new paradigm-shifting technology that can replace conventional monolithic space systems. Satellite "swarm" can be actively controlled such that a desirable synergetic behavior emerges from the interactions among spacecraft and between the spacecraft and the environment. Potential applications derived from such synergetic behaviors include sparse aperture radar interferometers, distributed sensors for weather monitoring, and communication relays. However, before satellite swarms can be implemented in real space missions, several technical challenges need to be overcome: (i) Developing realistic models of Smallsat dynamics and environmental disturbances; (ii) Swarm state estimation and communications architecture; and (iii) Swarm guidance, control and coordination to accomplish a variety of missions; and (iv) "Provability" of system properties under a variety of operating regimes and environmental disturbances.

Estimated TRL at beginning and end of contract: (Begin: 2 End: 3)

Technical Objectives and Work Plan

SSCI and University of Washington (Prof. Behcet Acikmese) propose to develop, integrate and test an innovative Distributed Intelligent Swarm Control & Utilization System (DISCUS). The DISCUS will be based on advanced distributed state estimation techniques, probabilistic guidance and control under collision avoidance and other relevant mission constraints, real-time contingency management including reactive collision avoidance with un-responsive team members, and low-level fault-tolerant control robust to subsystem and component failures. Decentralized estimation is based on using RSS and TOA sensors, and fusion of information from EO sensors. Guidance and Control is based on extensions of an innovative approach to swarm density control using a Markov Chain Monte Carlo (MCMC) approach with guaranteed satisfaction of the ergodicity, motion, and safety constraints. Reactive collision avoidance will be based on extensions of a suite of SAA algorithms previously developed or under development by SSCI, while fault tolerance will be achieved by combining SSCI's approach to FDIA with low-level baseline control. Focus on Phase I will be on algorithm development, initial integration of GNC algorithms, and feasibility demonstration on a simplified swarm simulation. Phase II will focus on maturation and integration of DISCUS, and its demonstration through hardware experiments.



NASA Applications

Swarms of Smallsats can replace current monolithic spacecraft while increasing the system flexibility and robustness. Such swarms have many potential NASA applications including replacement of Synthetic Aperture Radars, sparse aperture sensing and stellar interferometry and global broadband internet satellites. They could also provide global real-time space weather monitoring, and a survey of the geomagnetic field and its temporal evolution.

Non-NASA Applications

Several future commercial applications of Smallsat swarms such as remote sensing, on-orbit servicing, and sparse aperture imaging are viable. Smallsat swarms can be used for rapid communication and imaging tasks to provide situational awareness solutions needed by DoD and other federal agencies. New commercial space applications are viable as a result of having low-cost and rapid access to space.

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

H3.02-9356 - A 3D Printer Enabled, High Performing, Microgravity Compatible, and Versatile Sample Preparation Platform

PI: Season Wong

AI Biosciences, Inc. - COLLEGE STATION, TX



Identification and Significance of Innovation

NASA is investigating the near- and mid-term development of highly-desirable systems and technologies that can provide on orbit analysis to enhance capabilities and reduce sample return requirements. AI biosciences proposes to advance our compact and automated versatile sample preparation platform (VSPP) to process biological samples from various sample matrices (e.g., water, swab, urine) to yield high quality nucleic acid (DNA/RNA/mRNA) for downstream molecular analysis. This unit allows previously complicated, and crew time-intensive sample preparation processed to be carried out by a closed, turn-key system.

- No new hardware needed. Automated, medium-throughput work processes can be performed by existing hardware in space (a quick, reversible change to 3D printer) inside the MSG
- Simple and robust--reliable and reproducible operation in space
- High quality NA extraction--less interference and more sensitive analysis
- A closed cartridge system during operation--contamination and leaks-free

Estimated TRL at beginning and end of contract: (Begin: 4 End: 6)

Technical Objectives and Work Plan

- Design and assemble a working NA extraction prototype cartridge for downstream PCR and sequencing.
- Demonstrate NA extraction from water, swab (microbe on hardware surfaces), urine, and whole blood (pathogens or human DNA).
- Demonstrate mRNA extraction for gene expression analysis.
- Verify results by PCR, electrophoresis, or sequencing
- Establish device performance analysis for ISS applications.
- Work with subcontractor and future collaborators prior to Phase II to ensure the design and reactions are compatible with NASA protocols needed for flight certification.



Concept of using low-cost 3D printer to operate high-end sample preparation in microgravity. A. Gen-1 3D printer/extraction device using 96-well plate. B. Gen-2 VSPP to be developed in Phase 1 will process samples in enclosed pre-filled cartridges. C. Picture of a **Made-in-Space** 3D printer that is compatible with our setup.

NASA Applications

Microbial detection and monitoring in Advanced Life Support Systems; radiation exposure studies; latent infection detection/diagnostics; studies on effect of space flight on microbial gene expression and virulence; extraterrestrial life search. Our technology can also be commercialized for ISS utilization by offering a platform for researchers who need reliable and medium throughput sample preparation capability in space to carry out their work.

Non-NASA Applications

With advances in molecular diagnostics, life science, and forensics, there will be a vast increase in demand for instrumentation that can handle automated sample preparation with in a closed format to eliminate cross-contamination. Other applications of this VSPP include environmental monitoring, agriculture, homeland security, forensic analysis, and food production safety.

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

H1.01-9317 - High Capacity Multi-Stage Scroll Compressor for Mars Atmosphere Acquisition



PI: John Wilson

Air Squared Inc. - Broomfield, CO

Identification and Significance of Innovation

Building on a successful compressor development for MOXIE, the proposed innovation is a Multi-Stage Scroll Compressor (MSSC) that can be configured to support a store-and-utilize strategy (high pressure) or just collection (high flow) of Mars atmosphere. If a store-and-utilize approach is required, the MSSC is configured to pressurize the gas over the triple point (>77 PSIA), providing the ability to liquefy CO₂ downstream of the MSSC. If only collection is required, the MSSC can be configured to maximize flow at a pressures above 15 PSIA. There will be two "types" of MSSCs pursued during the Phase I effort, an orbiting and spinning MSSC. The orbiting MSSC has the advantage of longer design heritage and lowers associated risk, while the spinning MSSC has the benefit of achieving an aggressive size and weight target. Both types advance over state of the art mechanical compression technologies, like high-speed turbo-compressors. Size, weight, and power requirements are all reduced. Reliability is also improved, as both MSSCs operate at significantly lower speeds than turbo-compressors.

Estimated TRL at beginning and end of contract: (Begin: 4 End: 5)

Technical Objectives and Work Plan

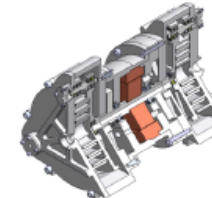
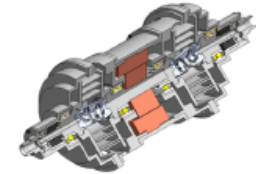
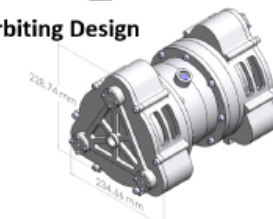
There are three primary objectives for Phase I. The first, is to test a representative orbiting scroll and spinning scroll compressor in Air Squared's environmental chamber to simulate the Mars atmosphere. The second is to design a full-scale spinning scroll and orbiting scroll MSSC based on data from testing. The third and final objective is to characterize the reliability of the spinning scroll MSSC, by running a representative spinning scroll prototype on a purpose-built life test stand, allowing for an understanding of bearing and tip seal wear over several months of continuous operation. The following work plan will accomplish all technical objectives:

- Task 1: Design and Fabrication of Supporting Test Hardware
- Task 2: Mars Atmospheric Test Stand Modification
- Task 3: Prototype Testing
- Task 4: Data Reduction
- Task 5: Spinning Scroll Life Test
- Task 6: Concept Design Study
- Task 7: Preliminary Design Study
- Task 8: Detailed (Final) Design
- Task 9: Final Conclusions and Reporting

Spinning Design



Orbiting Design



NASA Applications

With NASA identifying Mars as the primary focus for human exploration programs, ISRU is a crucial component in enabling future exploration or even Mars colonization. ISRU includes the production of rocket propellant, oxygen, and other resources harvested from the Martian atmosphere. As the atmospheric pressure of Mars is approximately 1% of Earth's, acquisition and pressurization of the Martian atmosphere will be a critical component of ISRU, as well as applications with demanding size, weight, and power requirements.

Non-NASA Applications

A spinning-scroll compressor has substantial size and weight savings over state of the art positive displacement compressors and vacuum pump products for aerospace applications. If successful, the spinning scroll MSSC will provide a pathway for tailoring the technology to new compressor and vacuum pump applications in the commercial aerospace industry.

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

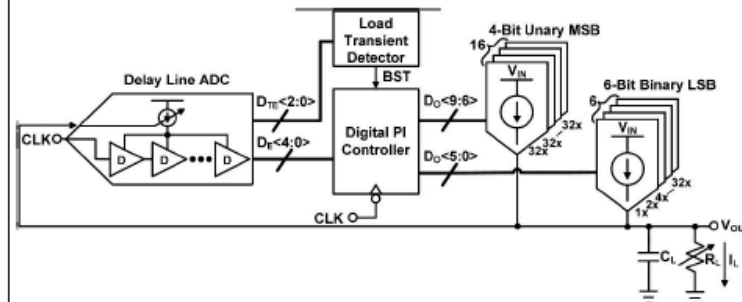
S4.04-8643 - Rad-Hard LDO



PI: Esko Mikkola
Alphacore, Inc. - Tempe, AZ

Identification and Significance of Innovation

Alphacore Inc. will develop a wide temperature range, digitally controlled linear low-dropout regulators (D-LDOs) for space and harsh environment applications. The radiation hardened-by design, digital intensive, unconditionally stable D-LDO offers a well-regulated supply for SoC power management applications, a transient-enhanced digital Proportional and Integration (PI) controller, without compromising the stability of the D-LDO, and boosted D-LDO dynamically boosted loop-gain during load transients. In the gain boosting mode, the D-LDO closed loop bandwidth is increased, resulting in reduced undershoot/overshoot and faster recovery of the output voltage. When the output voltage recovers to the desired level, the boost mode operation is disabled. The significance of this innovation is that rad-hard LDOs will be available for space missions at performance levels comparable to those for terrestrial applications. Alphacore and Arizona State University's proposed digital linear low-dropout regulator will be fully digitally controlled, enabling portability across process technologies.



Estimated TRL at beginning and end of contract: (Begin: 3 End: 4)

Technical Objectives and Work Plan

Objective 1: Design, fabrication and characterization of a delay-based ADC used in a D-LDO:

1. Develop detailed plan for the exact technical specifications to be targeted in this program
2. Design, layout and tape-out of delay-based ADC to be used in the D-LDO.
3. Develop system level model of the D-LDO

Objective 2: Fully Integrated D-LDO design:

1. Develop top-level transistor level implementation of the D-LDO, with a gain boost mode.
2. Schematic level top level simulations for load and line regulation, setting time.
3. Characterization of the taped-out delay based ADC

NASA Applications

- Europa
- Mars InSight, Mars Exploration, MAVEN
- Solar probes
- WFIRST
- ECOSTRESS, GeoCARB, HypIRI, MAIA, NISAR, InSAR, Pre-ACE, TEMPO, TROPICS
- ...and many more.

Non-NASA Applications

- High energy physics experiments
- Medical imaging
- Medical irradiation
- Nuclear weapon proliferation monitoring
- Radiation bio-hazard monitoring
- Commercial and civil space-based sensors

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

Z8.02-9571 - Efficient and Secure Network and Application Communications for Small Spacecraft



PI: MEHMET ADALIER
ANTARA TEKNIK LLC - GRANITE BAY, CA

Identification and Significance of Innovation

Complex missions away from Earth's resources require autonomous operations with minimal Earth contact and secure communications and networking topologies at various Quality of Service (QoS) levels to support swarms of small spacecraft. *Innovations:* 1) Efficient, secure, configurable, dynamic and highly scalable key management and chipper-suites at multiple QoS levels via algorithmic optimizations and asynchronous execution methods for the bundle protocol (bp) to augment DTN solutions based on Interplanetary Overlay Network; 2) Efficient and standards driven adaptation of the Constrained Application Protocol (CoAP) over bp (CoAP-over-bp) to enable secure and scalable low-power application communications systems for clusters of small spacecraft. *Significance:* Enable Autonomous and Complex Networks in space at multiple QoS levels. Minimize implementation footprint of the internetworking software, memory, and processing by infusing with space-hardened FPGAs/on the horizon compute technologies. Deliver higher security, performance, scalability to address technology gaps in NASA TA5.3.

Estimated TRL at beginning and end of contract: (Begin: 2 End: 4)

Technical Objectives and Work Plan

Objective/Task 1. Research, Define, Architect, and Document DTN compatible secure Key Management Methodology and associated chipper-suite(s) to address technology gaps as defined in NASA TA5.3.3. Investigate low-power One-pass Diffie-Hellman ECC based key-agreement/distribution protocols for multiple Quality of Service Levels and algorithmic optimizations for chipper-suites to support various mission types.

Objective/Task 2. Research, Define, Architect, and Document CoAP-over-bp to provide a DTN compatible, interoperable, low-power application communications protocol for clusters of small spacecraft. Investigate scalable autonomous communication mechanisms using CoAP-over-bp.

Objective/Task 3. Prototype, Model, Simulate, and Bench-test Key Management, chipper-suites and CoAP-over-bp within the ION framework to establish and document feasibility. Ensure scalability to support complex and time-varying networks.

Objective/Task 4. Show a Path towards a hardware/software infusion into practice by defining and documenting a Phase II Development Plan with performance goals, key technical and operational milestones and deliverables. Define relevant testing environments and document Mission Support Activity Plans and Commercialization Plan.



NASA Applications

A horizontal, fundamental enabling capability to support multiple NASA applications and missions.

Securely enable Autonomous Operations and Complex Network Topologies as described in TA5.3.

Enable missions that need scalable, flexible, secure, autonomous and bi-directional communications for swarms of spacecraft.

Enable complex and time-varying networks of spacecraft and sensors to share rich, near-real-time streams of information.

Non-NASA Applications

Public Service and Safety via interoperable communications and real-time information sharing among first responders during disasters

Resilient DoD Mobile Ad-hoc Networks to securely extend the reach and tactical agility of joint forces

IoT applications in stressed environments such as cargo and vehicle tracking, global asset tracking, smart-city M2M communications, and humanitarian relief

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

S4.05-8282 - Unique, Voltammetric Electrochemical Sensors for Organic Contaminants, with Excellent Discrimination, Based on Conducting Polymer-, Aptamer- and Other-Functionalized

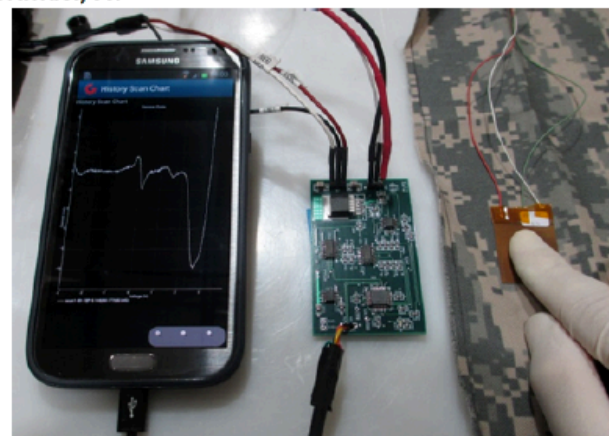
PI: Prasanna Chandrasekhar

Ashwin-Ushas Corp, Inc. - Holmdel, NJ



Identification and Significance of Innovation

In ongoing and recent prior work for the Army, this firm has developed a unique, patented technology for voltammetric electrochemical detection of toxic gases, chemical warfare agents, proteins such as Thrombin and Fibrinogen and other analytes. Features include: (1) Voltammetric detection yielding analyte "fingerprints" much like an IR spectrum for high discrimination. (2) 3-module construction (disposable sensing element; tiny Microcontroller; Android cellphone control interface). (3) Small (1cmX1cmX1mm), inexpensive (\$250), portable, thin, flexible, lightweight (2g), body-wearable, environmentally durable construction. (4) Operating temperature -40 to +80 C. (5) Detection times <5s. (6) Power 10 micro-W/cm². (7) Self-calibrating. The proposed work will further develop these for sensing contaminants of interest. It will further develop, optimize sensor, Microcontroller, Android interface, data-analysis algorithms, and sensor Form Factor, all specifically for the NASA application. It will include environmental durability, shelf-life and other tests.



Estimated TRL at beginning and end of contract: (Begin: 2 End: 6)

Technical Objectives and Work Plan

(1) Test a variety of differently functionalized sensing electrodes on Au/microporous membrane substrates, for detection of analytes of interest and interferences. (2) Optimize sensors to minimize detection limit and time, down-select best sensors. (3) Tailor and optimize interrogation (control) and data analysis (including peak ID) algorithms and databases residing on Microcontroller and Android cellphone control interface for the best sensors found, for all analytes. (4) Carry out 2nd round of iterative testing and optimization of physical sensor, interrogation algorithms and data analysis algorithms. (5) Test environmental durability, stability, shelf-life, operating temperature durability, battery life, and other relevant durability parameters. (6) Further refine Microcontroller, Android interface and associated software, demonstrating ability to simultaneously interrogate up to 5 or more sensors connected to a single Microcontroller, optimize Android/Microcontroller Bluetooth connection. (7) Miniaturize, further refine and finalize physical sensor Form Factor (size, shape, weight, method of deployment for NASA use), demonstrate such refined sensors. (8) Identify potential commercialization strategies and initial end-user tie-ups.

NASA Applications

Successful completion will lead to an entirely new, field-portable, body-wearable, handheld, voltammetric electrochemical sensor technology with "fingerprint" discrimination of analytes, for NASA application not only in contamination of spacecraft, but also, e.g., for fuel leaks.

Non-NASA Applications

Apart from the NASA application, commercial applications are in toxic gas and pesticide and detection in the agriculture, mining and industrial markets, where extant technologies have innumerable drawbacks. Based on recent surveys, the commercial/-industrial market is estimated at up to \$2B/year in the US alone.

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

S1.09-9887 - Regenerators for 10 Kelvin Cryocoolers



PI: Ali Kashani

Atlas Scientific - San Jose, CA

Identification and Significance of Innovation

NASA astrophysics and exploration missions require various enhancements in multi-stage cryocoolers. These include increased efficiency, reduced vibration and reductions in overall system mass and power consumption. For the coolers required, Stirling and pulse tube coolers offer the best opportunities. The efficiency of these coolers is limited by the effectiveness of low-temperature regenerators. Below about 60 K, two factors are key in reducing the effectiveness of regenerators. The heat capacity of most materials falls with decreasing temperature, thus, reducing the efficiency. Also, materials commonly used are only available in powder form, a form known to raise reliability issues. We will address both the aspect of high-efficiency and regenerator durability. A Rare Earth alloy, that below 60 K has a heat capacity higher than that of commonly used materials, will be configured in a well-defined porous matrix; Both the void fraction and the ratio of surface area to solid fraction of the regenerator matrix will be tailored using a new approach to achieve a high efficiency.

Estimated TRL at beginning and end of contract: (Begin: 1 End: 3)

Technical Objectives and Work Plan

We will develop a new technique to manufacture screen mesh and fiber felt regenerators from Er50Pr50, an alloy of Erbium (Er) and Praseodymium (Pr). Our analysis indicates that for coolers reaching 10 K the wire diameter needs to be below 20 μm to achieve high efficiency with either screen or felt regenerators. To accomplish this we envision using a new approach to achieve such fine-diameter Er50Pr50 wires. The new approach involves coating stainless steel wires as small as 5 μm in diameter with Er50Pr50 to form wires with a 20 μm outer diameter. Our Work Plan is to:

Develop optimal matrix designs for low temperature regenerators operating in the range of 10 to 60 K – determine the optimal dimensions of a particular geometry (coated fiber felt or coated screen mesh) as a function of temperature, and determine the optimal matrix porosity as a function of temperature. The modeling will be carried out using Sage™, an analysis and optimization tool for regenerative cryocoolers.

Acquire custom weave 400 mesh square-weave stainless steel screen using very fine wire.

Form Er50Pr50 coated screen and fiber matrix regenerators at Ames Laboratory of Iowa State University using a novel Vapor Deposition technique. Analyze the properties of the newly developed regenerator materials using the facilities at Ames Laboratory



NASA Applications

Astrophysical and exploration missions planned by NASA depend on the availability of reliable and efficient multi-stage cryocoolers. Advanced astrophysics missions such as JWST require low temperature cooling for detectors and their associated optics directly. Further, the long-term storage of cryogenic propellants, in particular liquid hydrogen is of interest. The conservation of propellant on long-term space flight will be an enabling technology for exploration and planetary missions.

Non-NASA Applications

Commercial applications which require cryocoolers that will benefit from high efficiency low-temperature regenerators include: - Superconducting electronics - MRI systems - Superconducting magnets for power generation and energy storage - SQUID magnetometers for heart and brain studies - HTS filters for communication - Liquefaction of gases - Cryopumps for semiconductor manufacturing.

Firm Contacts

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

S3.02-9225 - Ultra-Compact Center-Mounted Hollow Cathodes for Hall Effect Thrusters



PI: Zachary Taillefer
Busek Company, Inc. - Natick, MA

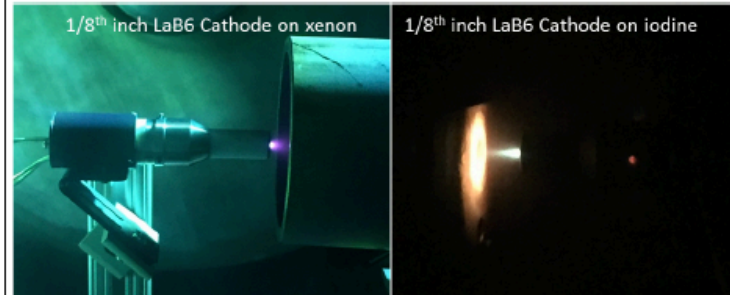
Identification and Significance of Innovation

The proposed innovation is a long lifetime, compact, iodine-compatible hollow cathode that can be mounted along the axis of a 600 W-class Hall effect thruster (HET). Testing at kilowatt power levels and above has shown that the thruster axis is the optimal position for thruster throttling and plume divergence. It also minimizes the impact of background conditions upon ground based performance measurements, reducing programmatic and technical risk to the end user. The proposed compact cathode will extend these benefits to low power Hall thrusters. Hollow cathodes are a critical, life-limiting component for HET and ion engines. Failure mechanisms include degradation, poisoning and evaporation of the electron emitter, keeper and emitter tube orifice erosion, and heater failure. These failure mechanisms will be addressed through the use of hexaboride emitters, optimal cathode position and a new, high temperature heater, respectively. By addressing these issues this cathode will achieve >10,000 hr lifetime and be more resistant to contamination than state-of-the-art BaO-W cathodes.

Estimated TRL at beginning and end of contract: (Begin: 3 End: 4)

Technical Objectives and Work Plan

Busek shall design, build and fully characterize through laboratory testing a compact hexaboride hollow cathode. The design will leverage Busek's experience with low power cathodes, high power center-mount cathodes and electrostatic thrusters. Currently, no hollow cathode exists which will operate reliably on iodine propellant for >100 hrs. The proposed cathode will increase the current state-of-the-art lifetime by two orders of magnitude. The work plan consists of 4 technical tasks including: 1) overall cathode design including considerations for center-mounting it on a BHT-600-I, 2) construction of the cathode with iodine compatible materials and a robust high-temperature heater, 3) testing the cathode in a relevant space environment on xenon and iodine propellants using plasma diagnostics to determine cathode behavior and estimate lifetime, and 4) integrated testing of a thruster-cathode system in relevant space environment on xenon to determine cathode performance. Task 5 is management and reporting of tasks to ensure proper execution of the program.



NASA Applications

The primary intent of this work is to improve hollow cathodes for low power HETs and create a more efficient propulsion system. NASA does not currently have a long-lifetime hollow cathode to support low power HETs running on iodine propellant. The compact cathode directly supports several HETs currently being developed at Busek and NASA, including the xenon fueled Busek BHT-600, an iodine compatible version of the BHT-600 and JPL's MaSMi thruster. These thrusters may propel NASA Discovery, New Frontiers and Explorers Class science missions.

Non-NASA Applications

This design will specifically support small spacecraft with power levels up to 1 kW. This regime is attractive for military, ESPA class and commercial missions due to high performance, small size, low mass, and relatively low cost. The low plume divergence enabled by an axial cathode minimizes spacecraft interactions, which is critical for geosynchronous spacecraft with lifetimes of 10-15 years.

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

S4.04-8391 - +500C Hi-Rel Rad Hard, Rugged Modulator

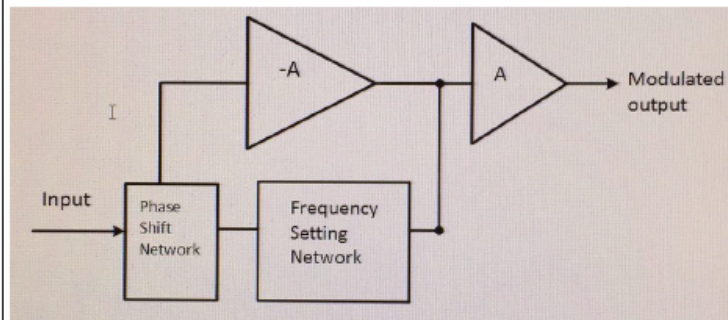


PI: Kouros Sariri

Chronos Technology (Div. of FMI, Inc.) - Huntington Beach, CA

Identification and Significance of Innovation

A conceptually validated feasibility study (in Phase I) for a compact, rugged, stable, low power, radiation hardened +500C radio frequency modulator (HTMX). It would be part of a transmitter used in extreme high temperature/ radhard space applications such as in-situ systems for Venusian surface (485C, 95 bar). Phase 1 will deliver a design roadmap for Phase 2 fabrication. The proposed modulator feasibility study would also address the packaging aspect of the HTMX, its miniaturization and manufacturing processes and guidelines to facilitate reliable and repeatable device fabrication and its full adaptation to mission deployment. HTMX will be housed in a rugged package that withstands pressure of 95 bar min at +500C. The HTMX configuration offers frequency scalable output, and commercial package footprints. It will be optimized to enable reliable transmission fidelity for the Venusians in-situ surface exploration. Keeping it simple will improve TRL of the modulator. Our approach will also enable very efficient adaptation of the design to ASK (amplitude shift key) modulation as well.



Estimated TRL at beginning and end of contract: (Begin: 2 End: 4)

Technical Objectives and Work Plan

Our proposed solution will include circuit design and modulation scheme that is highly compatible and avoids complex and power hungry circuits. A very efficient frequency modulator could be designed based on a voltage controlled oscillator (VCO) with the frequency control element represented by a +500C piezoelectric resonator instead of an inductor. The VCO circuit would require an amplifier which in this case would be based on high temperature GaN transistors. The VCO will also use a GaN varactor diode which offers a significantly lower leakage current than what is currently available. Hughes Research Labs (HRL) has expressed interest in supporting our work in designing GaN transistor and GaN varactor diode. Circuit investigation includes resonator design with sufficient frequency tuning range that would serve modulation bandwidth >200KHz. Resonator frequency vs. temperature will be optimized to deliver better than 50ppm frequency stability at 475C +/- 25C. The VCO modulator will operate from a single power supply and will provide sufficient signal amplification to drive external load of at least 15PF. Output waveform will be either sine or squarewave with 3V amplitude min. Modulator will be contained in one hermetically sealed package that will rugged and easy to install in the subsystem

NASA Applications

NASA missions to Venus and other hot planets. There will be other derivative outcomes from the same technology. There is potential to configure the GaN transistors used in PWM circuits. There are PWM circuits being planned to be used in power processing units (PPU) as part of space based electronic thrusters. The high temperature capable PWM could be positioned very close to the power switches without the need for large and heavy heat sink. Doing so will result in more efficient DC-DC boost convertors

Non-NASA Applications

Applications extend to more than one category and maps to multiple market segments. High temperature GaN transistor and varactor diode will always have their own potential applications in the harsh industrial, nuclear reactor, jet engine control and energy exploration. Varactor diode by itself has potential applications in system synchronization for networked down-hole monitoring systems.

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

Z2.01-9459 - Ultra-Lightweight MG Syntactic for Insulation in Extreme Environments



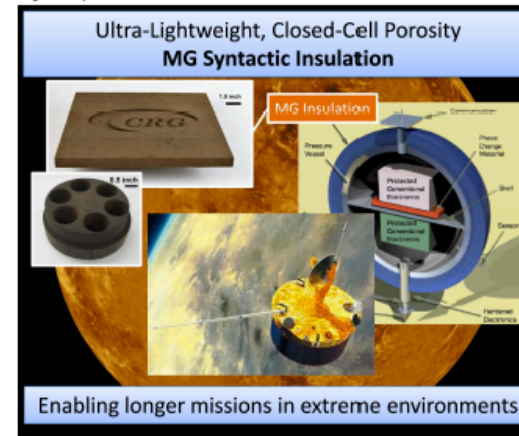
PI: Brian Henslee

Cornerstone Research Group, Inc. - Dayton, OH

Identification and Significance of Innovation

Improved external insulation for pressure vessels on exploration vehicles

- Enable longer mission durations in extreme environments
- Explore the surface of Venus and Jupiter's atmosphere
- Cross-applicability in many terrestrial applications
- 25% the density of microporous silica
- Thermal conductivity is comparable to the state of the art
- Closed-cell porosity: thermal conductivity not affected by gas density
- Intrinsically tough compared with ceramic counterparts
- Chemical and thermal stability to survive extreme environments
- Enables longer mission durations
- Affordable, scalable manufacturing



Estimated TRL at beginning and end of contract: (Begin: 2 End: 3)

Technical Objectives and Work Plan

Technical Objectives

1. To Formulate MG Syntactic for Extreme Environments
2. To Demonstrate Insulation Performance
3. To Determine Component Manufacturing Limits
4. To Demonstrate Concept Feasibility
5. To prepare for Phase II Prototype demonstration

Work Plan

- Task 1: Improve MG Syntactic formulation and Processing
Task 2: Characterize Insulation Performance
Task 3: Determine Castable Thickness
Task 4: Explore Post-Processability
Task 5: Demonstrate Overall Concept Feasibility
Task 6: Prepare for Phases II and III

NASA Applications

- Extreme environment insulation
- Venus lander
- Jupiter atmospheric probes
- Entry vehicle heat shields
- Fireproof insulation in crew spaces

Non-NASA Applications

- Fireproof building materials
- Low-flammability composites for transportation
- Industrial process pipe insulation
- Combustion/exhaust systems
- Black-box/flight recorder case
- Fireproof composite case for portable power

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

S3.06-8949 - A Two-Phase Pumped Loop Evaporator with Adaptive Flow Distribution for Large Area Cooling

PI: Weibo Chen

Creare, LLC - Hanover, NH



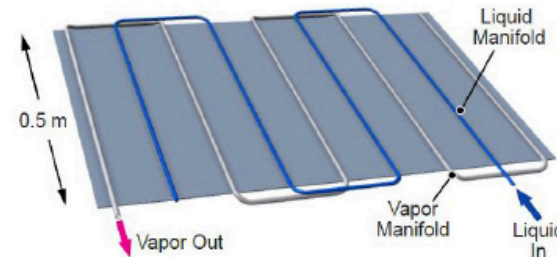
Identification and Significance of Innovation

Large spacecraft need a reconfigurable thermal control system to cool multiple instruments and reject heat through multiple radiators
A microgravity-compatible evaporator having a large cooling area to maintain the temperatures of multiple electronics and instruments

- Very large cooling area to accommodate a large number of loads with different heat flux densities, power levels, sizes, and shapes
- Adaptive flow distribution ability to prevent dryout in high heat flux areas
- Unique internal microchannel configuration to provide strong structural support for cover plates

Benefits

- Simplify vehicle level system integration
- Reduce pumping power by reducing liquid recirculation
- Lightweight and low liquid holdup
- Microgravity compatible operation



Lightweight Evaporator with Adaptive Flow Distribution for Large Cooling Area of 0.5 m x 1 m.
Evaporator Mass of 2.8 kg (not incl. manifold).

Estimated TRL at beginning and end of contract: (Begin: 2 End: 3)

Technical Objectives and Work Plan

Technical Objectives

- Advanced capillary structure to redistribute liquid over a large distance
- Reliable fabrication processes
- Lightweight and rugged structure

Phase I Work Plan

- Assemble and test a proof-of-concept subscale evaporator
 - Demonstrate ability to accommodate a large spatial heat flux variation
- Conduct fabrication trials to demonstrate critical fabrication processes
- Optimize evaporator design for high thermal performance and lightweight design

NASA Applications

- Thermal control system for spacecraft to Saturn's moon Enceladus
- Two-phase pumped loops for future remote sensing science missions, including Surface Water and Ocean Topography (SWOT)
- Two-phase pumped loops for large spacecraft with a large number of instruments

Non-NASA Applications

- Two-phase thermal control systems in commercial and military satellites, aircraft, and vehicles
- Thermal management systems for high-power electronics systems

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

Z8.01-9758 - Fiber Fed Advanced Pulsed Plasma Thruster (APPT)



PI: Curtis Woodruff
CU Aerospace, LLC - Champaign, IL

Identification and Significance of Innovation

CU Aerospace (CUA) proposes the development of the Advanced Pulsed Plasma Thruster (APPT) that will enable cis-lunar and deep space missions for small satellites. While classic PPT technology is mature, it has historically been limited by its size and propellant load to small Delta-V applications. A recent advancement by CUA, Monofilament Vaporization Propulsion (MVP), uses extrusion 3D printing technology to provide polymer propellant to an electrothermal thruster. APPT will leverage this advancement, using PTFE fiber to allow for class-leading propellant capacity and more reliable feed than previous PPT designs. APPT is inherently safe, containing no pressurants or hazardous materials, significantly reducing range safety concerns. A 1U APPT, operating at 1200 seconds Isp, will provide 10,400 N-s total impulse, allowing for 1,400 m/s Delta-V for an 8 kg CubeSat. Increasing to a 2U form factor increases total impulse to 30,000 N-s, allowing for a Delta-V exceeding 4 km/s.

Estimated TRL at beginning and end of contract: (Begin: 4 End: 5)

Technical Objectives and Work Plan

The primary technical objectives of Phase I are to prove stable, reliable operation of a breadboard high-throughput APPT system, obtain preliminary thrust performance, and refine the prototype design for development and testing of an integrated Phase II system ready for flight qualification. Individual technical objectives and risk reduction conducted during Phase I will include:

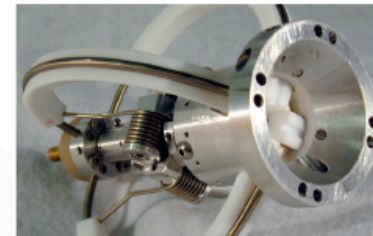
- Fabricate a PPT-11 thruster head modified for PTFE fiber feed
- Demonstrate reliable and accurate metering of the propellant feed system
- Demonstrate reliable discharge ignition and evaporation of Teflon fiber in a continuous fashion
- Experimentally demonstrate specific impulse and thrust capabilities in a simulated space environment for a nominal 75 W system
- Design a high-throughput 1U APPT flight-like system with low specific mass
- Refine system models of discharge pulse and performance from thrust stand results to guide Phase II prototype development

CUA anticipates delivering to NASA an integrated system by the end of Phase II which includes the advanced thruster head, PTFE filament feed system, and an ACS subsystem.

Advanced Pulsed Plasma Thruster



CUAerospace



CU Aerospace's PPT-11 modified for continuous PTFE fiber feed

1U volume
10,400 N-s Total Impulse

NASA Applications

With the demonstrated high performance of CUAs PPT-11 (Isp > 1200 seconds) and the innovative propellant feed and storage system of the recently developed CUA MVP thruster, APPT exceeds the goals of the Z8.01 topic and outperforms previous state of the art PPT systems, as well as newer technologies such as electrospray and helicon thrusters. With an anticipated 10,400 N-s total impulse from a 1U system, large orbit transfers and even inclination changes of tens of degrees are now available to smaller satellites.

Non-NASA Applications

Commercial interest in nano-/small-satellites continues to grow, and it is more important than ever that these satellites have access to propulsion to extend their asset time on orbit. The APPT provides a compact, light-weight, non-hazardous, high volumetric impulse propulsion technology solution available in a family of sizes to meet the differing mission needs of users in DOD/industry/academia.

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

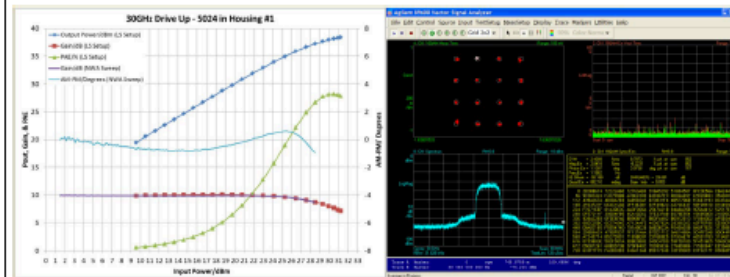
H9.04-8557 - GaN MMIC Ka-Band Power Amplifier



PI: James Moniz
Custom MMIC Design Services Inc. - Chelmsford, MA

Identification and Significance of Innovation

NASA is seeking innovative Advanced RF Platform technologies at the physical level, specifically Ka-Band high efficiency high linearity microwave 10 to 20 Watt solid state power amplifiers (SSPAs), to meet the needs of future space missions utilizing complex modulation for communications and sensor applications. Space missions require the smallest size, lowest power, space qualifiable hardware components leading to the choice of monolithic microwave integrated circuit (MMIC) technology. In Phase I of this SBIR, Custom MMIC Design Services, Inc. (CMDS) will analyze the GaN MMIC technologies from the available domestic foundries (NGST, Qorvo, HRL) and select best GaN HEMT foundry and process technology to achieve Ka-Band high efficiency high linearity microwave 10 to 20 Watt SSPA. CMDS, utilizing the appropriate CAD tools, will thoroughly design and develop the required MMIC PA.



Estimated TRL at beginning and end of contract: (Begin: 3 End: 3)

Technical Objectives and Work Plan

The technical objectives are: 1) select the best GaN MMIC process and devices that meets the requirement of a 10-20 W PA at Ka-Band with high power added efficiency and linearity, 2) simulate and optimize the RF performance with the appropriate MMIC CAD tools of a Ka-Band MMIC PA with 10-20 W of output power with high efficiency and linearity utilizing the process selected in 1), and 3) prepare all the necessary design rule check (DRC) and layout versus schematic (LVS) documentation to assure clean layouts ready for fabrication submission to facilitate the first pass of GaN MMIC fabrication on Phase II contract selection. To achieve the objectives of above, CMDS has divided the project into ten major work plan tasks. These tasks are:

1. Foundry study, evaluation, and trade-off analysis
2. Design S/X/Ka-Band MMIC LNAs and variants
3. Produce preliminary MMIC layouts
4. Perform preliminary electromagnetic (EM) simulations
5. Generate required technical reports
6. EM analysis of circuit designs
7. Variability analysis of circuit designs
8. Prepare test cells/breakouts for analysis and debug
9. Generate data summaries for each design for fabrication
10. Prepare the mask set(s) for submission to the foundry (DRC, LVS etc.)

NASA Applications

This GaN MMIC linear PA project success, a new 10-20 Watt linear high efficiency PA MMIC, will allow us to develop other similar PAs for NASA and NASA subcontractors. We have done this before having been the recipient of derivative 5 W linear PA contracts from NASA Goddard for "25 to 27 GHz Power Amplifier" and NASA JPL for "35 GHz Power Amplifier for Radar Applications". More of this work will take place at different frequencies and different power levels with the success of this project.

Non-NASA Applications

Gallium Nitride PA MMICs are in short supply. As a proven entity that can create a significant number of products in a short space of time, Custom MMIC with this contract can establish itself very quickly as a significant contributor of high efficiency linear GaN PAs to the RF block diagrams of both commercial and military systems at Ka-Band and then can quickly move to other frequency bands.

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

Z8.03-8424 - High Power Radiation Tolerant CubeSat Power System

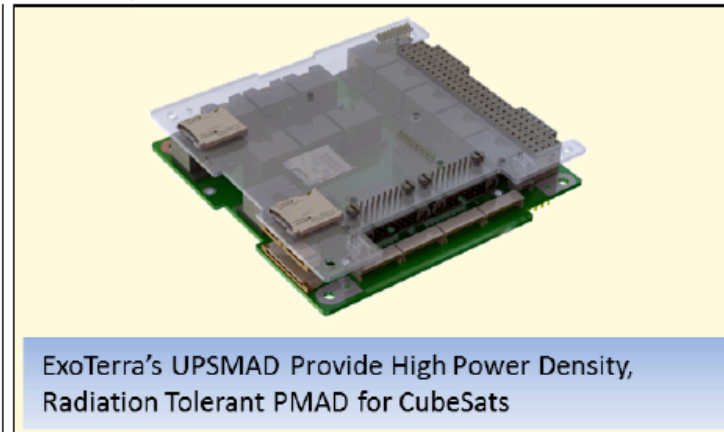


PI: Chris Thein

ExoTerra Resource, LLC - Littleton, CO

Identification and Significance of Innovation

ExoTerra's Universal Power Storage, Management, And Distribution module enables CubeSat and SmallSat end users a highly flexible, radiation tolerant, turn-key power system. The versatile power processing architecture of our concept has unprecedented implications for user procurement: a single system can be adjusted through software to meet multiple applications instead of multiple types of fixed capability assemblies. The architecture provides a rapid and responsive solution to the creation of configurable SmallSat powertrains. In spacecraft with more stringent reliability requirements, multiple units could be integrated together and have on-orbit re-configurability to compensate for potential power processing element losses. In addition, at 200W, the system doubles the power capability of current systems to enable higher power Cubesat Missions at supports higher radiation tolerance for operation beyond LEO.



ExoTerra's UPSMAD Provide High Power Density, Radiation Tolerant PMAD for CubeSats

Estimated TRL at beginning and end of contract: (Begin: 3 End: 4)

Technical Objectives and Work Plan

Phase I: The primary goal of the project is to demonstrate a functional PMAD and storage solution. The concept is being designed to fit in a standard CubeSat while also offering unprecedented flexibility, built in batteries, and multiple user power inputs and outputs. During the project we design the electronics and the battery pack. The electronics and battery pack will be fabricated and preliminary testing will be done to ensure correct operation. Total system efficiency and system quiescent power will be characterized measured input power vs output. The software based control will be demonstrated by commanding operation of the PMAD through a serial terminal. Phase II: We incorporate lessons learned from Phase I into a qualification unit design. We then build the qual unit and begin qualification testing, including shock, vibration, static load and thermal cycling. Phase III: We complete qualification testing and perform a flight demonstration.

NASA Applications

A low cost, radiation tolerant, high efficiency combined PMAD and battery module has several NASA applications. With these, NASA can perform low cost interplanetary exploration with CubeSats by enabling higher power telecom, EP and sensors with radiation tolerant electronics. This enables coordinated observation, infrastructure, and shotgun exploration applications.

Non-NASA Applications

CubeSat's are becoming a more dominant presence in space due to their high capability in relation to their much lower cost of entry to space. There is a growing demand for low cost, well designed, radiation tolerant CubeSat components, as is evidenced by ExoTerra's recent designing of a new 1kW PMAD for Pumpkin, Inc. ExoTerra fills this void with the highly functional UPSMAD.

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

Z3.02-9720 - Manufacturing Decision Tree Model Optimization for Finishing Additive Manufactured Components

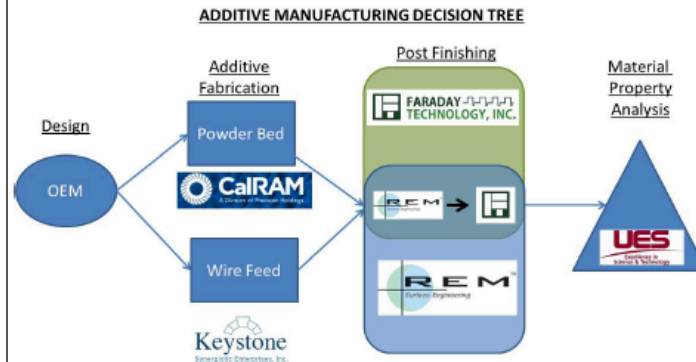
PI: Timothy Hall

Faraday Technology, Inc. - Englewood, OH



Identification and Significance of Innovation

This Phase I program addresses the challenge of gaining the necessary knowledge needed to support certification of additive manufacturing (AM) hardware and achieving the desired surface finish and mechanical properties on high value components produced by AM. To achieve this goal Faraday Technology Inc., will work with team members at UES Inc., CalRAM Inc., Keystone Synergistic Enterprise Inc., and REM Surface Engineering to develop the necessary empirical knowledge to produce a manufacturing decision tree model (MDTM) that will enable the part designer to reduce the cycle time required produce the desired part with the required surface finish. It is envisioned that the outcome of this Phase I/II program would be a working MDTM that has the potential to diagnose the best manufacturing pathway to produce a wide range of high-value components with various shapes and contours.



Estimated TRL at beginning and end of contract: (Begin: 2 End: 5)

Technical Objectives and Work Plan

The MDTM will be designed to select the appropriate build pathway to form the desired component and improve the as-built surface finish on the required areas while also determining the necessary secondary steps to achieve the desired surface finish on all required surfaces. The specific Phase I objectives are: 1) design a single complex part geometry that represents many of the typical component geometries, 2) build that part using available powder bed (CalRAM) and wire fed (Keystone) additive technologies, 3) finish all the parts surfaces to an RMS of 32 using conventional machining, sonic (REM), and electrochemical processes (Faraday), 4) evaluate the parts mechanical and microstructural properties (UES), and 5) understand each steps respective processing and dimensions/finish time, and the potential of the process to maintain material functionality. This work will be carried out over the 6 tasks of Phase I with the goal of completing the following milestones: 1) Design of single complex part for analysis, 2) Produce the part via both wire fed and powder bed techniques, 3) Finish the part via both electrochemical and isotropic finishing techniques, 4) Analyze of the final finish and contour of the processed part, 5) Evaluate the material microstructure and mechanical properties, 6) Qualify the time of each manufacturing step, and 7) Evaluation of the efficacy of the model.

NASA Applications

We envision this technology application in other areas including: space re-entry vehicles, diver and attitude control systems, gun barrels, hypersonic propulsion, nuclear reactors, gas turbines, or any other technology that suffers from weight restriction and high manufacturing cost due to the large amount of material consumption and extensive machining steps.

Non-NASA Applications

In addition to the NASA, the proposed technology will be of interest to other agencies, including Army, Navy, and Air Force. Applications for this technology include DOE ground energy systems, DoD tactical and strategic missiles, enhancing component efficiency, thrust, specific impulse, and maneuvering.

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NASA SBIR/STTR Technologies

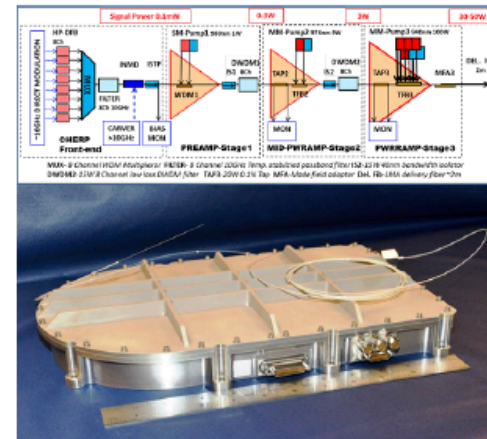
H9.01-8624 - High Power (50W) WDM Space Lasercom 1.5um Fiber Laser Transmitter



PI: Doruk Engin
Fibertek, Inc. - Herndon, VA

Identification and Significance of Innovation

Fibertek proposes to develop a spaceflight prototype, wideband, high power ($P_{avg} \sim 50W$) polarization maintaining (PM) laser transmitter suitable for Wavelength Division Multiplexed (WDM) very high data rate NASA Deep Space Optical Communication (DSOC). The proposal is innovative because Fibertek will demonstrate 50W average, 10 kW peak power with $>20nm$ flat gain bandwidth and with 20% DC to optical efficiency out of a space qualifiable laser transmitter. Such a performance can support up to 8, 4W Wavelength Division Multiplexed (WDM) multi rate PPM channels with 256 ary modulation. It can also support 20, 2.5W 10GHz (200GHz total) burst mode RZ-DPSK WDM channels. The proposed 10x scaling of the average and peak power performance for the transmitter presents potential for $>100x$ scaling of the currently available laser communication rates for space.



Estimated TRL at beginning and end of contract: (Begin: 3 End: 5)

Technical Objectives and Work Plan

- Demonstrate high efficiency ($\sim 20\%$ DC-to-optical), $>10W$ 2-stage EDFA with high gain bandwidth (30-nm, gain-flat 0.5-dB), C-band (1532-1565nm). The amplifier will be able to support $>2kW$ peak power and 128 PPM ary modulation.
- Demonstrate High efficiency ($\sim 20\%$ DC-to-optical), 50W 3-stage EDFA with high gain bandwidth (20-nm, gain-flat 0.5-dB), C-band (1546-1566nm). The amplifier will be able to support $>4kW$ peak power and >128 PPM ary modulation.
- Carry out a comprehensive experimental trade study using the most promising 3-5 COTS large area mode (LMA) Er/Yb fibers (including Rad hardened fiber) for 30-50W average, 2-15kW peak power WDM application. Trade study will include characterization of the fiber non-linearity impact on signal integrity for both multi-rate PPM and burst mode RZ-DPSK formats.
- Demonstrate Compact High Extinction Ratio Power Efficient (CHERP) multi-rate PPM Transmitter Front-end approach scalable to multiple wavelengths.
- Detail WDM fiber-amplifier modeling and simulations including photo darkening due to radiation and fiber nonlinearities. Baseline models using Phase 1 experimental results and define optimum laser Tx design for

NASA Applications

- Space laser comm transmitter for ISS/LEO/GEO platforms, similar to NASA technology demonstrator missions, like LLCD and LCRD.
- High-data rate, multi-channel laser transmitters, as an adjunct high-volume data link for Earth Science missions, like hyper-spectral imaging.
- NASA SCaN strategy to enable large science data volume returns for deep space missions.
- Laser transmitter developments for Earth Science, including ASCENDS, CO2 lidar, CH4/H2O, and Wind Lidar.

Non-NASA Applications

- High data-rate, low SWaP, laser transmitters for optical communication from LEO/GEO satellites
- High data-rate real-time feed from multiple UAVs via LEO/GEO crosslinks

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NASA SBIR/STTR Technologies

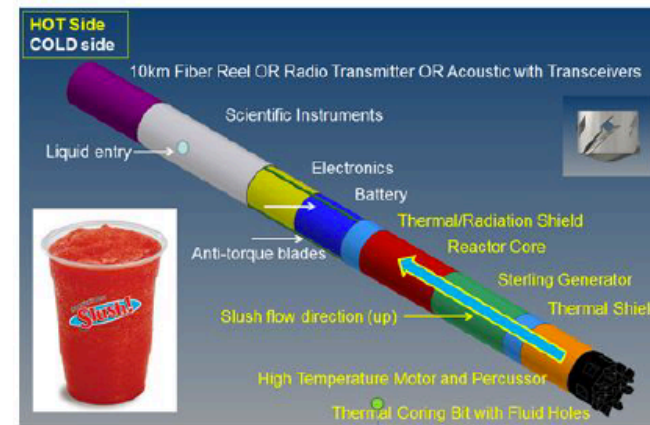
S4.02-8511 - SLUSH: Europa Hybrid Deep Drill



PI: Kris Zacny
Honeybee Robotics, Ltd. - Brooklyn, NY

Identification and Significance of Innovation

Europa has been a primary target in search for past or present life, because it is still geologically active. The search for life, however, requires reaching of either subglacial lakes or the ocean. Theory and observation indicate that the icy shell is approximately ~5 to 30 km thick. Typical deep probes are either hot point or mechanical. We propose a hybrid approach that takes the best from the two options and either eliminates or reduces risks posed by each of the options above. SLUSH is a hot-point electro-mechanical drill that cuts through ice using highly efficient rotary-percussive action, and melts chips with its hot bit to form slush. Slush moves up the hole where it refreezes behind the drill. SLUSH is approximately 14 cm in diameter and 2.5 m long.



Estimated TRL at beginning and end of contract: (Begin: 2 End: 4)

Technical Objectives and Work Plan

The main objective of this proposal is to develop SLUSH deep drill. In Phase 1, we will investigate drill bit design for cutting and melting ice and chips/slush transport. In Phase 2, we will fabricated and test TRL 4 system. Phase 1 goals are to:

1. Finalize Requirements
2. Slush high level design Structural Testing Samples
3. Bit development and drilling
4. Chips transport
5. Thermal evaluation
6. SLUSH detailed system level design

NASA Applications

SLUSH is designed to reach oceans on Europa and possibly Enceladus. The system could also be deployed on Mars. SLUSH subsystems could be used on other planetary missions: motors, bits, percussive system can be infused into any other surface missions requiring sample acquisition (Venus In Situ Explorer, South Pole Aitken Basin Sample Return).

Non-NASA Applications

Penetration to subglacial lakes in Antarctica and Greenland. Aseptic sampling of subglacial lakes is critical to astrobiology - a drill that can go through DHMR and is fully decoupled from the surface will be ideal for such an application. SLUSH could be used to deploy instruments in ice. Since this is a robotic system, the 'field' season will no longer be constrained to summer months.

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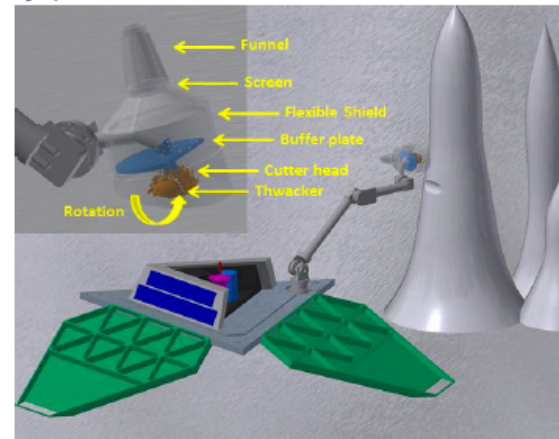
NASA SBIR/STTR Technologies
S4.02-9693 - Europa Drum Sampler (EDuS)



PI: Kris Zacny
Honeybee Robotics, Ltd. - Brooklyn, NY

Identification and Significance of Innovation

Ocean Worlds (Europa, Enceladus) are the most promising bodies to find life. The next mission to Europa, will have a lander with a sampling system. Sampling is needed to capture samples since life can not be detected from an orbit. The mission will launch in 2024 time frame, hence the time is ideal for developing various sampling systems that could be infused into the mission. We propose to develop sampler based on terrestrial roadheader used in mining and construction. The digging approach is very robust to surface topography and can deal with soft and very hard materials. We designed a system around the roadheader cutter that allows easy capture and delivery of sieved samples to instruments.



Estimated TRL at beginning and end of contract: (Begin: 2 End: 4)

Technical Objectives and Work Plan

The main objective of this proposal is to develop sample acquisition system for Europa lander. In Phase 1, we will perform trade studies and breadboarding to reach TRL4. In Phase 2, we will fabricated and test TRL 6 system. Phase 1 goals are:

1. Finalize Requirements
2. Perform trades and Quick and Dirty Tests
3. Design TRL4 EDuS breadboard.
4. Test TRL4 EDuS in a walk-in freezer in Europa analog materials
5. Perform trades for the Europa lander backup sampler
6. Design TRL6 EDuS and backup sampler (if needed)

NASA Applications

NASA missions include Europa mission as well as future mission to the Ocean Worlds (Europa, Enceladus, Titan etc.). The sampling system could also be used on NF missions: South Pole Aitken Basin Sample Return, Venus In Situ Explorer, Comer Nuclear Sample Return.

Non-NASA Applications

Non-NASA applications include sample acquisition and transfer from robotic systems in hazardous environments: nuclear site disasters, chemical spills, environmentally sensitive areas. The sampling systems could also be used by commercial companies with interest in ISRU: Planetary Resources, Deep Space Industries, and Shackleton Energy.

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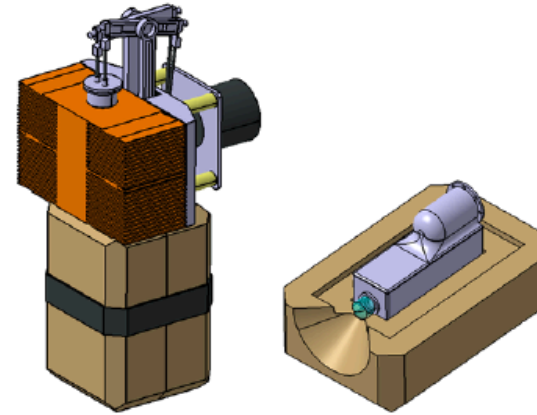
NASA SBIR/STTR Technologies
S4.04-8372 - High Temperature Stirling Cooler



PI: Andrew Maurer
Honeybee Robotics, Ltd. - Brooklyn, NY

Identification and Significance of Innovation

Although Honeybee and others have made huge advances in developing mechanisms, motors, and electronics for use in high temperature/high pressure environments such as the surface of Venus (460C), certain types of critical electronic and sensing technologies are inherently temperature sensitive. The lack of high temperature tolerant cameras and optical sensors has, to date, prevented up-close in-situ analysis of the Venusian surface. In this SBIR we will close that technology gap by developing a miniature Stirling cooler, suitable for integration with a sensor package at the end of an effector or robot arm, which is capable of keeping conventional electronics cool outside of the spacecraft body in the high temperature Venus environment. This advance would vastly expand the list of technologies which can be deployed on the surface of Venus, and correspondingly advance the types of science that can be performed. We will demonstrate in Phase-I a brassboard system at high temperature, followed by a flight like system in full Venusian conditions in Phase-II.



Estimated TRL at beginning and end of contract: (Begin: 2 End: 4)

Technical Objectives and Work Plan

In Phase-I we will:

- Conduct detailed trade studies of the chiller, motor, linkage, and cold enclosure architecture, selecting the construction which best meets the demands of the environment
- Performed detailed design of a brassboard model chiller
- Procure and assemble the brassboard unit
- Demonstrate the operation and survival of the unit in a 460C ambient environment, including a demonstration payload sensor, such as an off-the-shelf USB microscope
- Time permitting, conduct a life test of the demonstrator at temperature

NASA Applications

We believe it is inevitable that electrically powered active coolers will be a part of the next high temperature exploration missions. Future rigorous science activities on Venus or Mercury all but demand small, efficient, cooling technologies for the many types of instruments and detectors which fundamentally cannot be adapted to operate at elevated temperatures. Likewise, NASA-sponsored earth science programs in hot locales like boreholes, volcanoes, and deep sea vents may similarly benefit.

Non-NASA Applications

This development is ideally suited for use by the oil and gas sector for inspection and sensing of oil and gas boreholes. In addition to the high temperature plus tight spaces make this miniaturized development for end effectors a "perfect fit." HT mechanisms are also used inside engine fairings. A small, reliable, chiller could be an enabling technology for engine and aerospace test equipment.

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

S1.02-8426 - A High Efficiency 400W GaN Amplifier for X-Band Radar Remote Sensing Using >50 VDC FETs



PI: Gabriele Formicone

Integra Technologies, Inc. - El Segundo, CA

Identification and Significance of Innovation

The proposed innovation is a high efficiency 400W two-stage power amplifier for X-Band RADAR applications. Phase I will investigate a ~50W GaN transistor die with 0.25 μ m gate length designed and fabricated by Integra Technologies. This device will be evaluated for gain, power and efficiency at X-band with operation at 50V, 75V and possibly at 100V. Phase II will require transistor die scaling based on the Phase I results to create a packaged transistor(s) that achieves >200W peak power. The RF impedance matching circuits will include fundamental and 2nd harmonic tuning to optimize efficiency by creating a Class J mode design. Class J is effective in improving efficiency when optimizing reactance tuning at the fundamental and 2nd harmonic only. The amplifier PCBA materials, components, and layout topology will be selected for reliability under high pulsed power conditions, including thermal considerations, breakdown under low pressure environments, including multipaction effects, and high mechanical stresses.

Estimated TRL at beginning and end of contract: (Begin: 3 End: 4)

Technical Objectives and Work Plan

Create a compact amplifier design: The demonstration device in Phase I will define the expected matching circuit impedances and elements required to reach high efficiency and a power goal of ~100W with a single transistor die at X-band. The Phase I goal is to define the expected circuit board size and layout for a two stage amplifier that achieves 400W of peak power at X-Band with a 30% duty cycle. Develop a base line for High efficiency Class J amplification: Beyond the investigation into device modeling at the fundamental frequencies to allow for proper impedance matching, the demonstration amplifier will be used to validate Class J configuration with fundamental and 2nd harmonic tuned to achieve high efficiency. The goal for Phase I is a device with greater than 50% efficiency for a 30% duty cycle pulsed X-band amplifier stage at ~50W output power. The research project will achieve the technical objectives by completing the following milestones:

- Design, build, and test a single GaN die with 0.25 μ m gate length, manufactured by Integra Technologies, Inc., for baseline technology performance and appraisal operated at 50V, 75V and possibly at 100V
- Design a new GaN Transistor device for optimum X-Band Performance operating at 75 and 100 VDC
- Design a pallet amplifier to achieve the Power and Efficiency Goals of the sub-topic requirement.



NASA Applications

A target application for this pulsed power amplifier can be RADAR for active remote sensing of Earth or potentially other non-terrestrial objects. If operation at 100 VDC in X-band is achieved, the transmitter could operate directly from the DC voltage bus of the spacecraft with minimal or un-necessary DC-DC converter. The successful development of this high efficiency X-band amplifier concept can be leveraged by NASA for other RADAR applications at other wavelengths.

Non-NASA Applications

The use of higher efficiency and higher power X-band GaN pulsed amplifiers will allow for improved power management for commercial, weather and military radar applications.

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

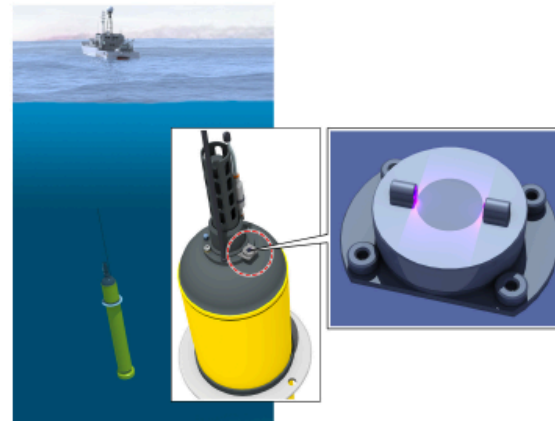
S1.08-8821 - Luminescent Sensors for Ocean Water Monitoring



PI: Jesus Delgado Alonso
Intelligent Optical Systems, Inc. - Torrance, CA

Identification and Significance of Innovation

Monitoring ocean acidification, which results from the accumulation of CO₂, is of critical interest, and NASA space-based global measurements of atmospheric and ocean CO₂ must be complemented with in-situ water analysis measurements. Monitoring ocean pH accurately over large areas has proved to be extremely difficult, and classic sensor technology, based on potentiometric measurements (pH electrodes), have shown significant limitations: current instruments are expensive and do not monitor pH directly, and thus need complex signal compensation to measure accurately, and require frequent calibration. Luminescence-based sensors have demonstrated stability superior to electrodes for water monitoring, and indicator-based analysis can measure seawater pH directly with the highest accuracy. Intelligent Optical Systems plans to develop novel sensor devices for monitoring seawater pH, based on recently developed indicator-based luminescent material for pH monitoring, which has exhibited extremely high stability and sensitivity.



Estimated TRL at beginning and end of contract: (Begin: 3 End: 5)

Technical Objectives and Work Plan

The overall goal of this project is to demonstrate the feasibility of a small, low-cost pH sensor for monitoring ocean acidification. The following specific objectives have been established in order to reach this goal: 1) Demonstrate a luminescent sensor exhibiting 0.002 pH resolution or better in seawater, in the 7 to 9 pH range; 2) Demonstrate effective antifouling; 3) Demonstrate potential for long term stability; and 4) Demonstrate sensor element replacement with no need for recalibration. The following tasks have been established to reach these objectives: 1) Prepare and optimize materials sensitive to pH; 2) Perform preliminary testing and select doped polymer supports for pH monitoring; 3) Evaluate sensor materials at a wide range of temperatures and pressure; 4) Analytically characterize the pH sensor; and 5) Determine optimal parameters for implementing anti-biofouling by UV illumination.

NASA Applications

A low-cost high-performance sensor for seawater pH, and multiparameter devices for monitoring dissolved CO₂ and dissolved oxygen in-situ are essential to current and future NASA space missions such as Active Sensing of CO₂ Emissions over Nights, Days, and Seasons (ASCENDS), Orbiting Carbon Observatory-2 (OCO-2), and Geostationary Coastal and Air Pollution Events (GEO-CAPE).

Non-NASA Applications

The combination of pH and dissolved oxygen monitoring will be valuable not only for ocean studies but in the growing aquaculture market, which is expected to exceed \$200 billion by 2020. Our sensors, initially developed for seawater, will also find application in the water quality monitoring market, which is projected to reach \$3.6 billion by 2020.

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

Z6.01-8732 - FLASHRAD: A 3D Rad Hard Memory Module For High Performance Space Computers

PI: James Yamaguchi

Irvine Sensors Corporation - Costa Mesa, CA



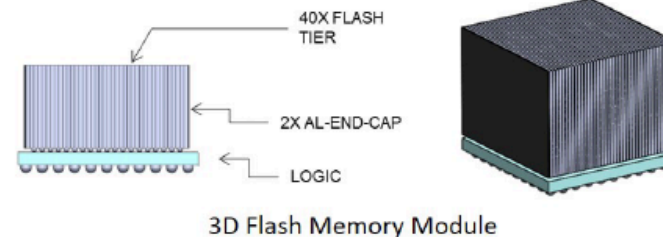
Identification and Significance of Innovation

The computing capabilities of onboard spacecraft are a major limiting factor for accomplishing many classes of future missions. Although technology development efforts are underway that will provide improvements to spacecraft CPUs they do not address the limitations of current onboard memory systems. Effective execution of data-intensive operations requires high-bandwidth, low-latency memory systems to maximize processor usage. Data being generated on a mission require large amounts of non-volatile memory in order to store this data for later transmission back to earth. These memory systems must be capable of providing operational robustness and fault tolerance required for space applications. To support the needs for NASA's HPSC, it is proposed that this research investigate the challenges in developing a space-qualified, 3D COTS Flash module supplemented with a custom RHBD controller. Focus will be on developing a NAND Flash module that could be used for SSRs to help increase the memory densities, lower power and cost, and achieve higher data throughput.

Estimated TRL at beginning and end of contract: (Begin: 2 End: 3)

Technical Objectives and Work Plan

The work for this Phase I research will address the goal of demonstrating a baseline system of COTS Flash memory integrated with a custom RH memory controller (RHMC) that offers high memory capacity, robust reliably, increased bandwidth, and improved SWAP characteristics needed for harsh space environments. To achieve enhanced reliability utilizing standard COTS components, the work will focus on developing a 3D Flash memory module (3DFMM) utilizing ISC's stacking technology in combination with a custom RHBD memory controller chip using Ga Tech's advanced 3D ASIC design capabilities. Leveraging advanced processing techniques in the RHMC can mitigate radiation effects such as SEE and SEFI typically experienced with COTS components. The RHMC would include features such as EDAC, overprovisioning, wear-leveling, bad block management, block scrubbing, garbage collection, n-modular redundancy support, and other features. The 3DFMM will support SRIO to simplify interconnectivity, allow for daisy chaining to build very large memory arrays, provide integrated redundancy, and module-kill functionality where required. The 3DFMM will be configured to allow seamless integration with NASA's HPSC through a SRIO interface. The 3DFMM can directly be utilized as (SSRs) since the memory controller provides the necessary flash management for reliability and longevity.



NASA Applications

The 3D memory module would allow for high bandwidth capabilities, increase memory density and dynamic error correction that could ultimately be used for NASA's HPSC and high memory density SSRs. Interplanetary missions and space telescopes are other possible applications. Further, this technology eventually will allow NASA to access a broader range of capabilities that can be brought to space.

Non-NASA Applications

The 3D COTS Flash module can be foreseen to enter markets where the ability to dynamically correct for memory errors is important in a harsh environment or where the electronics cannot be readily repaired or replaced. Military and commercial communication satellites, space-based surveillance and reconnaissance, and downhole electronics are applications where robust electronics are in demand.

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

S1.11-8595 - WOLFEChip: Wholly-integrated Optofluidic Laser-induced Fluorescence
Electrophoresis Chip

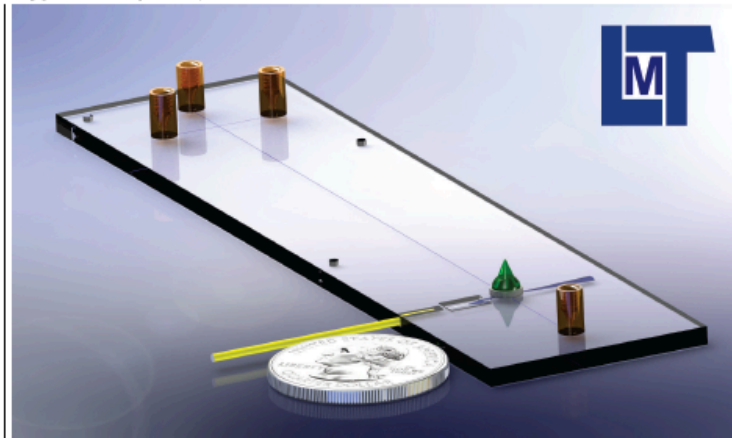
PI: Nathan Bramall

Leiden Measurement Technology - Sunnyvale, CA



Identification and Significance of Innovation

Leiden Measurement Technology LLC (LMT) proposes to design and build the Wholly-integrated Optofluidic Laser-induced Fluorescence Electrophoresis Chip (WOLFEChip), a microchip capillary electrophoresis (MCE) system using a miniaturized optofluidic approach for packaging all optical elements necessary for laser-induced fluorescence (LIF) on-chip. MCE-LIF is a highly-sensitive means of detecting and quantifying important chemical species. Existing optical hardware for MCE-LIF has been shown to have the sensitivity and specificity for the detection of life on Ocean Worlds as it can measure the abundance and chirality of amino acids down to 5-nM levels. LMT proposes to develop MCE-LIF hardware that greatly miniaturizes traditional LIF optical systems by integrating all necessary optical elements on-chip. This not only considerably reduces the size and mass of existing MCE-LIF systems but also makes them much more immune to vibrations as all optical elements are integral to the microchip. Development of WOLFEChip will make MCE-LIF hardware even more well-suited for flight.



Estimated TRL at beginning and end of contract: (Begin: 2 End: 4)

Technical Objectives and Work Plan

The Phase I technical objectives are to (1) design on-chip optical structures suitable for performing MCE-LIF in a fused-silica microchip including fully-3D spherical lenses, 3D waveguides, and heat-bonded microlenses; (2) manufacture the designs developed as part of Objective 1 for testing; (3) Test and evaluate the manufactured test chips to verify and understand the performance of the microchip designs and manufacturing process; and (4) Determine key parameters for the WOLFEChip Phase II instrument. LMT will take an iterative approach with each of these objectives and will use the testing/evaluation results of each manufactured chip to inform the next stage of design.

NASA Applications

WOLFEChip is especially well-suited for detecting life on Ocean Worlds in the solar system (e.g., Europa, Titan, Enceladus) as well as other smaller bodies (e.g., asteroids, comets) and rocky planets (e.g., Mars) as WOLFEChip (1) uses very small amounts of reagents; (2) is miniaturized, immune to vibrations, and use very little power; (3) requires only μ L-amounts of liquid sample for high-quality measurements, it can be used on icy-plume sampling missions, surface-lander missions, and even more extensive rover/cryobot exploration missions.

Non-NASA Applications

WOLFEChip can be used in many different situations including (1) environmental research of terrestrial and marine waters; (2) process control and monitoring of closed water systems; (3) pharmaceutical research; (4) monitoring and identification of organic pollution in water, soils, and sediments (e.g., pesticides, fuels, drugs); (5) the detection of biological and chemical weapons.

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

S1.04-9669 - Tunable, High-Power Terahertz Quantum Cascade Laser Local Oscillator



PI: Tsungyu Kao

LongWave Photonics - Mountain View, CA

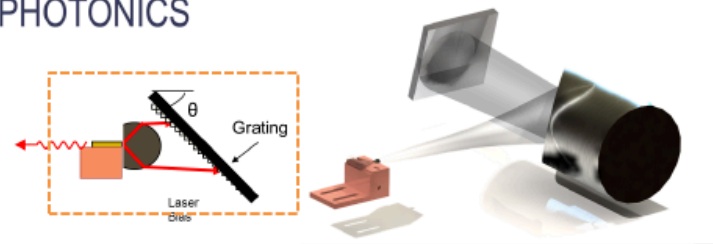
Identification and Significance of Innovation

NASA and NASA funded missions/instruments such as Aura/MLS, SOFIA/GREAT and STO-2 have demonstrated the need for local oscillator (LO) sources between 30 and 300 μm (1 and 10 THz). For observations >2 THz, technologically mature microwave sources typically have microwatt power levels which are insufficient to act as LOs for a heterodyne receiver.

LongWave Photonics is proposing to develop a high power, frequency tunable, phase/frequency-locked, single mode External Cavity THz quantum cascade laser (ECT-QCL) system with >2 mW average power output and a clear path to increase the power to >10 mW. The source will be frequency tunable over 100's of GHz, with center frequencies ranging from 2 to 5 THz. The laser will be phase/frequency stabilized to achieve narrow line widths (<100 kHz).

LONGWAVE PHOTONICS

External Cavity Tunable-QCL



Estimated TRL at beginning and end of contract: (Begin: 3 End: 3)

Technical Objectives and Work Plan

Technical Objectives and Work Plan

Objectives 1) Demonstrate Efficient Frequency Selective External Feedback Based on Echelle Grating

Objectives 2) Implement Proof of Concept External Cavity QCL

Objectives 3) Design and Simulation of Adiabatic Mode Converter for QCL Chip
Task 1): Demonstrate Efficient Frequency Selective External Feedback Based on Echelle Grating

Echelle Grating with $>70\%$ efficiency centering around 4.3 to 4.9 THz will be designed, fabricated and tested

Task 2): Implement Proof of Concept External Cavity QCL

External Cavity THz laser based on SISF waveguide will be build and tested. Various optical losses will be introduced to study the material gain, mirror losses and optical components.

Task 3): Design and Simulation of Adiabatic Mode Converter for QCL Chip
Horn-like adiabatic mode converter for metal-metal waveguide will be designed and simulated in order to reduce power reflection from laser end facets.

NASA Applications

NASA applications include the use of the QCL as an LO for >2 THz receivers for future remote sensing missions. Here the narrow line width (<100 kHz) of the QCLs can be used to resolve Doppler-limited low pressure gasses ($\sim\text{MHz}$ linewidth). The external cavity QCL LO would be a frequency tunable, compact replacement for any gas-laser LO. This turn-key, table-top, high power (10mW at Phase II), frequency stabilized THz source can provide a platform for developing other key components in the receiver channel.

Non-NASA Applications

There are increasing needs for local oscillators to perform heterodyne measurement at THz range from non-NASA academic and government researchers. Also the frequency tunability has great appeals toward researchers in high resolution gas spectroscopy field. Long-term applications include industrial uses for trace gas detection and THz detector/imager power calibration over narrow bands.

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

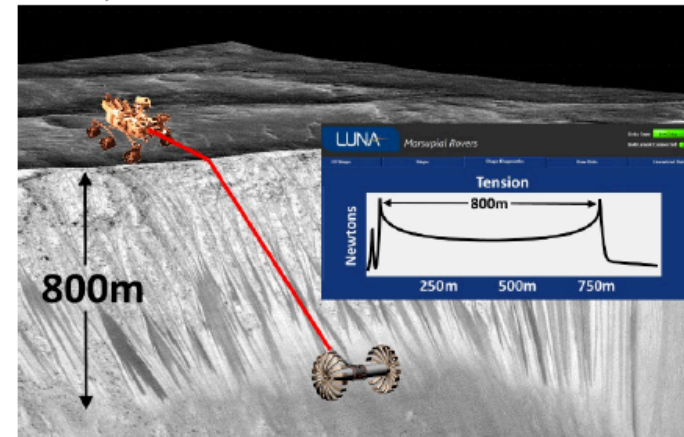
S4.02-9202 - Extended Length Marsupial Rover Sensing Tether



PI: Emily Templeton
Luna Innovations, Inc. - Roanoke, VA

Identification and Significance of Innovation

Luna proposes to continue development of its marsupial rover sensing tether by extending the length of the sensing technology out to a kilometer. By sensing the distributed tension and curvature of a tether that connects a marsupial rover to its base station the MaRS Tether can alert the base station to possible pinch points, snagged cables, or high tension. By extending the length and robustness of the sensing capabilities of the MaRS Tether, Luna will greatly increase the operating range of lightweight, highly mobile rovers enabling more complex missions.



Estimated TRL at beginning and end of contract: (Begin: 3 End: 4)

Technical Objectives and Work Plan

The primary objective of this Phase I effort is to demonstrate the feasibility of expanding the capabilities of the MaRS Tether system to enable its use in a wider variety of exploration mission scenarios.

Objective 1: Determine length, spatial resolution, update rate, and other key parameters for Phase I development.

Objective 2: Demonstrate expanded capabilities on a tension-only sensor.

Objective 3: Create performance trade off matrix.

Objective 4: Develop the transition and commercialization strategy.

To achieve these objectives, Luna has outlined the following tasks

Task 1: Kickoff project and determine metrics for success

Task 2: Develop tension measurement for long lengths

Task 3: Decrease sensitivity to motion

Task 4: Develop spot scan mode

Task 5: Demonstrate system performance.

Task 6: Create trade-off matrix the for tether design space

Task 7: Develop commercialization plan and Phase II tasks

NASA Applications

Robotic exploration missions (TA 4.1.1, TA 4.2.6) including:

Mars Exploration; Astrobiology Field Lab; Network landers; Europa explorer; By extending the range of the sensing tether technology, this project will increase the scope of robotic exploration missions. For example, missions to explore the large Martian craters that show evidence of liquid water through recurring slope lineae will require tether lengths of several hundreds of meters.

Non-NASA Applications

Unmanned underwater vehicles (UUVs)

Large scale robotic manipulators

Improved operations of payload tethers from rotorcraft

Search and rescue robotics

Non destructive evaluation tool tip location

Strain sensing on large scale aircraft and other structures

Firm Contacts

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

H9.04-8956 - Optically Assisted Analog-to-Digital Converter for Next Generation "Software Defined" Radios

PI: Chris Thomas

MaXentric Technologies, LLC - Fort Lee, NJ



Identification and Significance of Innovation

An optically assisted ADC enabling next generation software defined radios is proposed. The ADC will have the capability of very broadband spectrum capture and digitization with high sampling rate and high ENOB.

- Leading designers in Integrated Circuits, Data converters, and Optical Systems
- RADHARD space qualified and high performance (CMOS-SOI process)
- Taking advantage of both CMOS-SOI and optical sampling
- ADC universal input depending on application (electrical or optical inputs)

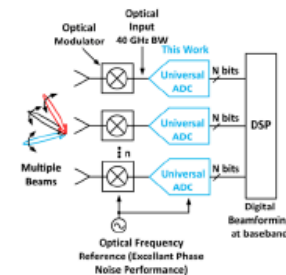


Fig. 1a. Universal ADC in a digital phased array system.

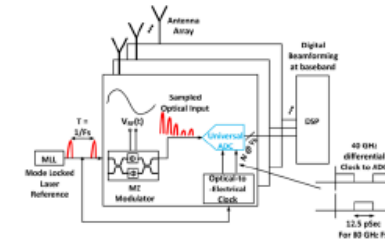


Fig. 1b. Universal ADC in an optically assisted system.

Estimated TRL at beginning and end of contract: (Begin: 2 End: 4)

Technical Objectives and Work Plan

- Universal ADC with flexible interface
- Sampling rate of 100 GS/sec for high speed full spectrum digitization
- Greater than 8b ENOB for high resolution applications
- Targeting 80 dB FS SFDR for highly linear applications
- Targeting < 500 mW for power constrained applications
- COTs demo of commercial components and optical setup
- Investigating full integration of optical interface

NASA Applications

- High bandwidth communications ($>> 1$ GHz)
- High resolution and high speed imaging in space
- True software defined radio (antenna to ADC)
- Reconfigurable receivers

Non-NASA Applications

- Commercial 5G phased array with ultra-high BW
- True software defined radio (antenna to ADC)
- High speed and high data-rate imaging (automotive, air, etc)
- Reconfigurable receivers (ISM, TV band cognitive radio)

Firm Contacts

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

S2.01-9655 - Next-Generation Deformable Mirrors for Astronomical Coronagraphy by Utilizing PMN-PT Single Crystal Stack Actuators in integration with Driver ASIC

PI: Xingtao Wu

Microscale, Inc. - Woburn, MA



Identification and Significance of Innovation

The innovation leverages on our experience in developing stack actuator DM system with integrated ASIC driver electronics, enabling the next-generation DM-ASIC systems, featured with:

- Electro-mechanical performance exceeding traditional piezoelectric DMs by about 5 times;
- Reduced number of wires from thousands to several tens;
- Reduction of the power dissipation by two (2) orders of magnitude, and shrinking of the form factor (weight/size) of the DM driver electronics by up to two (2) orders of magnitude;
- Reducing the DM cost by about 5 times; and
- Filling the NASA Technology Gap (Gap ID: CG-3) on DM and associating driver electronics connectors/cables as listed in the recently released Exoplanet Exploration Program Technology Plan Appendix 2017

Estimated TRL at beginning and end of contract: (Begin: 2 End: 3)

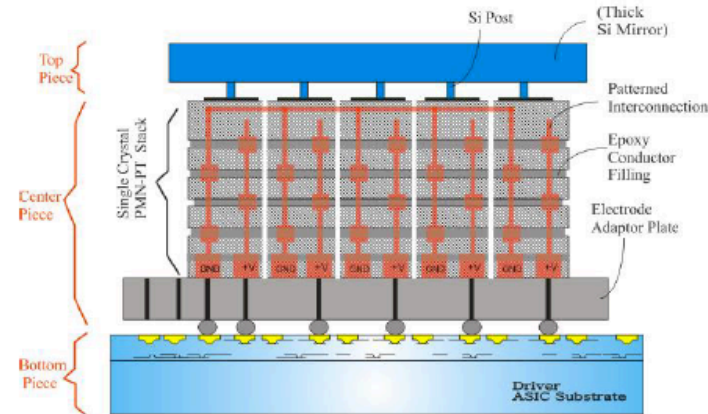
Technical Objectives and Work Plan

The proposed DM-ASIC architecture comprises of three main building blocks, namely from the bottom to the top, there are (1) a novel switch-mode driver ASIC, (2) the micro-fabricated single crystal PMN-PT stack actuator array (with an electrode adaptor plate element for interconnection to driver ASIC), and (3) the Silicon-on-Insulator (SOI) mirror element, as shown in the illustration Figure.

During the Phase I development, we will focus on the actuator and DM development. For the Phase I demonstration, we plan to use the existing driver ASIC evaluation board to carry on joint test with the DM if time allows. The fully integrated DM-ASIC systems will be developed during the Phase II project if funded.

The Phase I has four technical objectives:

1. **Stack actuator and DM modeling**
2. **Process development to fabricate the pre-structured single crystal PMN-PT cube**
3. **Prototyping and test of the batch-fabricated single crystal PMN-PT stack actuators**
4. **Prototyping and test of a Phase I stack actuator array DM for demonstration**



NASA Applications

Visible Nulling Coronagraph (VNC), single aperture far-infrared observatory (SAFIR), Extrasolar Planetary Imaging Coronagraph (EPIC), Terrestrial Planet Finder (TPF), Submillimeter Probe of the Evolutionary Cosmic Structure (SPECs), the Stellar Imager (SI) and the Earth Atmospheric Solar occultation Imager (EASI).

Non-NASA Applications

Retinal imaging and laser surgery instrumentations, ophthalmology and other microscope applications, optical communications, telescopes, direct retinal display, and projection display.

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

S1.02-9973 - Deployable Ka/W Dual Band Cylindrical Parabolic Antenna including feed support structure



PI: Christopher Pelzmann
MMA Design, LLC - Loveland, CO

Identification and Significance of Innovation

The need for large radio frequency (RF) apertures in space has long driven technology developments that enable aperture sizes that exceed the allowable volume within a launch vehicle fairing. As the operating wavelength of these systems increases, the difficulty and cost grow exponentially. Large aperture high frequency antennas are of significant interest for science instruments and commercial communications. NASA weather and precipitation monitoring efforts utilize RF sensing instruments operating at Ka and W band frequencies. The proposed deployable high frequency antenna, will enable future satellite missions with one-dimensional parabolic dual frequency RF apertures operating at 35 GHz and 94 GHz in sizes ranging from <2 to 32 square meters (4 meters x 8 meters) and larger. This antenna will be adaptable to other government and commercial applications across a broad range of frequencies

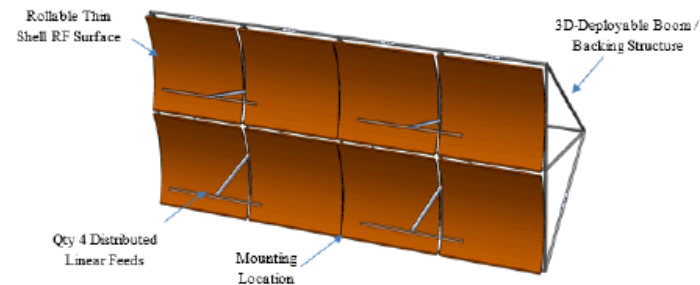


Figure 1: Deployed 1-D Parabolic Antenna

Estimated TRL at beginning and end of contract: (Begin: 2 End: 4)

Technical Objectives and Work Plan

MMA will develop preliminary designs and performance models of a deployable thin shell reflector antenna to support frequencies up to 94 GHz. Design concepts are modular and scalable and modeling efforts will support apertures of roughly 2, 8, and 32 sq. meters. Key design elements required for deployment and antenna performance will be validated by breadboard hardware development and testing. Test results will be used to anchor and refine performance models and designs for phase II efforts.

NASA Applications

High frequency antennas support next generation weather satellites monitoring precipitation, hurricanes, and other atmospheric phenomena. Deployable antennas will support larger apertures and/or smaller, more affordable launch systems for these missions. High frequencies are also targeted for next generation communications requirements offering dramatic increases in data transfer rates for RF systems that can also be supported by this technology.

Non-NASA Applications

There are a wide variety of military, civil, and commercial users with significant interest Ka/VW band frequency spectrum. All of these are influenced by the same trend to use deployable antenna technologies to fit their needs onto smaller satellites that are more rapidly developed and launched within smaller budgets while preserving the maximum data output/throughput value.

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

S2.01-8536 - Proximity Glare Suppression for Astronomical Coronagraphy



PI: Karun Vijayraghavan
Nanohmics, Inc. - Austin, TX

Identification and Significance of Innovation

Glare suppression is a critical technology for coronagraphs, exoplanet imagers, and advanced telescopes. Nanohmics has developed the "Thermodot" technology, a sub-wavelength structured surface that couples EM waves into an absorbing material with vanishingly small reflectance. The Thermodot process has been shown to outperform multi-layer coatings in optical performance and environmental robustness. Anti-reflection surface structures have been used on glasses, crystalline materials, curved optics, and polymers. We will extend to absorbing substrates, producing non-reflecting super-black absorbing materials for space-based telescopes. Advantages of the innovation: 1) Applicability to flexible, non-planar substrates, appliques; 2) Environmental ruggedness - nanostructures are patterned in the substrate; 3) No delamination, CTE mismatch, or chemical aging; 4) No flaking, particle formation, or outgassing; 5) Can be applied in well-defined areas, with sharp edges, or with apodization; 6) Demonstrated anti-reflection performance over 2 octaves, spanning VIS-LWIR spectral bands.

Estimated TRL at beginning and end of contract: (Begin: 3 End: 4)

Technical Objectives and Work Plan

We envision the primary goal of Phase I to be the development of particular set of Thermodot-derived structures and a process for fabricating a rugged, space-compatible super-black light-absorbing material integrated with antireflection structures that exhibits broadband spectral absorption at normal and large angles of incidence, supported by modeling and analysis, with a plan to move forward into optimization and increased performance in Phase II.

Work Plan:

Task 1: Program kickoff with NASA sponsor

Task 2: Modeling and analysis of various index-graded absorber designs

Task 3: Investigation of nanoparticle masks for selective electroless metal plating

Task 4: Development of oxide absorbing coating integrated with nanostructured surface

Task 5: Characterize optical and environmental properties of super-black absorbing materials

Task 6: Develop Phase II program plan

Surface topography of super-black absorber



Removal of Ni nanoparticle mask



Etching of Thermodot structure into an absorbing substrate

NASA Applications

Initial commercialization efforts will focus on delivering super-black absorber components and variants to NASA for coronagraphs and other advanced space imaging applications. Further applications are evident with Dept. of Defense and Dept. of Homeland Security agencies – these will drive early evaluation opportunities and revised product requirements in the commercial sector.

Non-NASA Applications

Developing strategic partnerships early in the adoption phase has been the key to our prior successes. During the early Phase I efforts and beyond, Nanohmics will work to establish key industry relationships and already has documented partnerships with Raytheon SAS, a major aerospace and imaging systems contractor for both terrestrial and space applications.

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

S1.07-8853 - Coded Aperture Techniques for High-Throughput Imaging Spectroscopy



PI: Yancey Sechrest
Nova Photonics, Inc. - Princeton, NJ

Identification and Significance of Innovation

We propose the use of programmable, two-dimensional (2D) coded apertures for high-throughput imaging spectroscopy. Spatially-varying, 2D, transmissive or reflective encoded mask, such as a hadamard or bernoulli random matrix, can be leveraged to realize high-throughput variants of many standard imaging spectroscopy techniques with throughput enhancements surpassing 50-100x compared to slit-based systems. In addition, recent advances in fast-switching spatial light modulators enable the reprogramming of mask encoding on the millisecond timescale. The combination these two technologies enables a wide array of potential innovations for hyperspectral imaging systems offering high-throughput, compressive measurement, with significant operational-flexibility. In this proposal, we target the application of these techniques to the development of a high-throughput, pushbroom imaging spectrometer for planetary science applications.

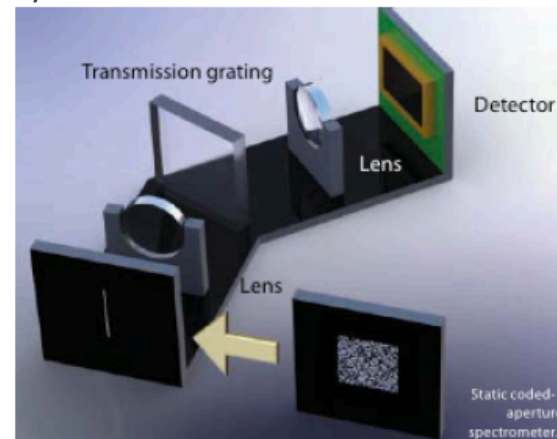
Estimated TRL at beginning and end of contract: (Begin: 2 End: 3)

Technical Objectives and Work Plan

The technical objectives for this proposal are the following:

1. Demonstrate reconstruction of hyperspectral data cube for conditions simulating an airborne coded aperture imaging spectrometer using numerical model applied to data from the AVIRIS database.
2. Construct and test coded aperture spectrometer experimental setup using motorized first mirror and DLP micromirror device.
3. Demonstrate reconstruction of hyperspectral data cube for panoramic scene from experimental data taken using a motorized first mirror.

Our work plan is to develop a numerical model of an airborne coded aperture imaging spectrometer (CAS). We have previously developed models for 1-D spatial data sets, and we will extend this model to 2-D images. The algorithms will be tested on the case of successive images translating across a fixed mask. Further, we will assemble a CAS lab-setup with a scannable mirror to test the translating-field concept. The experimental data will then be used to validate the model and reconstruction algorithms.



NASA Applications

Airborne/orbital imaging spectroscopy for terrestrial, lunar, martian, or planetoid orbiter missions. Hyperspectral imaging camera for lander missions. Imaging and integral field spectroscopy for astrophysical observations.

Non-NASA Applications

Remote sensing platform for scientific, defense, or industrial applications. Precision agriculture (or site specific crop management), and land and forest management (e.g. sustainable forest management). Industrial imaging for quality assurance/quality control (e.g. food safety inspection) and automation.

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

S1.02-9156 - Improved Microwave Photonic Links via Receive-Side Nonlinear Signal Processing



PI: Gregory Kanter
NuCrypt LLC - Evanston, IL

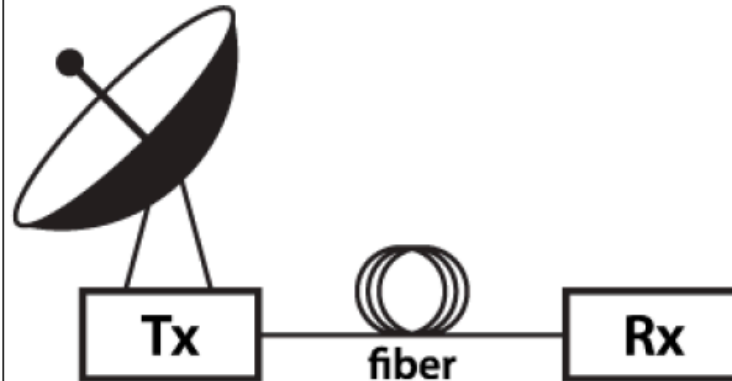
Identification and Significance of Innovation

We propose to significantly enhance the state-of-the-art of photonically-assisted microwave measurement and distribution systems by incorporating a nonlinear optical process into the system design. Photonic-assisted systems are used in satellites and other space and power constrained vehicles to reduce the size, weight, and power required to measure and distribute microwave signals. Our novel design further incorporates a nonlinearity that can improve the dynamic range of the system without causing a reduction in the inherent noise-figure, thus eliminating a trade-off currently encountered when designing microwave-photonic systems. The proposed technology can also optically down-convert the microwave signal of interest thereby eliminating electronic mixers that can otherwise add loss, reduce dynamic range, and constrain the operating frequency range. The resulting high performance system can be useful for a wide range of microwave/RF measurements including radar, communications, and remote sensing.

Estimated TRL at beginning and end of contract: (Begin: 2 End: 3)

Technical Objectives and Work Plan

Our objective is to show the feasibility of using a novel design to improve the dynamic range of a photonically assisted microwave measurement and distribution system. The work plan consists of numerically modeling various designs, demonstrating the principle of using a nonlinear process to improve system performance, and testing suitable modulator technologies for incorporation into future prototypes. We expect detailed modeling to indicate that a substantial (e.g. 10 dB) improvement in dynamic range is attainable at a fixed noise figure by incorporating our novel techniques. We further expect to validate a modulation technology well suited to high performance applications and future photonic integration. The outcome of the Phase-I effort will be a proof-of-principle experimental validation of the method and a specific design with documented target metrics including dynamic range. A working prototype of this design will be pursued in a Phase-II effort.



NASA Applications

The proposed technology allows for high performance measurement and distribution of microwave signals as is commonly required in radar, navigation, communications, and remote sensing. It is well suited for space and power constrained systems like satellite and spacecraft applications. For instance, various missions aimed at climate science such as the Global Precipitation Measurement Mission Core Observatory could benefit, as well as communications and navigation systems such as the NASA deep space network and radar-based landing systems.

Non-NASA Applications

This technology is well suited to civilian and military aerospace and naval microwave applications like radar, communications, and remote sensing. It is also a good fit for portable microwave instrumentation systems as are used for installation and servicing of microwave technologies, and for backhaul links of cell towers used in terrestrial wireless communication networks.

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies
S1.10-8993 - Optical Flywheel for Yb⁺ Ion Clock



PI: Andrey Matsko
OEwaves, Inc. - Pasadena, CA, CA

Identification and Significance of Innovation

OEwaves Inc. offers to develop and demonstrate an extended cavity ultra-stable 436 nm diode laser system that features the properties required for long duration space applications. The system will be based on a semiconductor laser locked to a monolithic microcavity using self injection locking technique. *This technique results in a complete suppression of mode hops in the laser during its operational lifetime. The microcavity will not only stabilize the frequency of the laser, but will also be used to measure and stabilize the power of the laser. Furthermore, the microcavity provides a modulatable laser that features exceptionally low residual amplitude modulation, allowing a robust lock to the clock transition of interest.*

The laser is intended as an optical local oscillator (LO) suitable for Yb⁺ ion clock. The LO will deliver the same performance as the best existing high-end laboratory Fabry-Perot resonator-based LOs — which are large, expensive, and fragile table-mounted instruments—but in a robust, 100 cc volume module that is inexpensive and consumes small power.

Estimated TRL at beginning and end of contract: (Begin: 1 End: 3)

Technical Objectives and Work Plan

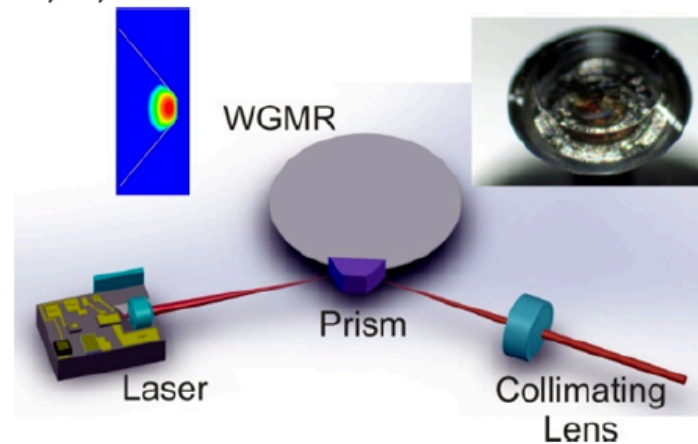
The objective of Phase I of this SBIR project is to design and validate theoretically, numerically, and experimentally a WGM resonator-based laser characterized with the following properties:
Laser wavelength: 436 nm (Frankfurt Laser Company or another vendor);
Power: 1 mW; Reference resonator quality factor exceeding 10⁹; Mode hop free operation; Frequency stability exceeding 5x10⁻¹⁵ in a second (corresponds to a sub-Hz linewidth); Low-RAM frequency actuation (relative amplitude modulation, RAM, less than -60 dB). The minimum bandwidth of the fast frequency actuator is 100 kHz, with a minimum tuning range of 0.1 GHz;
Thermal actuation range: 10 GHz; Acceleration sensitivity better than 10⁻¹¹/g;
Space radiation hardened; Survive launch environment; Package size less than 100 cc; Projected cost below \$30,000 (in volume production).

Work Plan:

Task #1: Design a WGM resonator having 5x10⁻¹⁵ relative frequency stability at 1s integration time

Task #2: Demonstrate a 436 nm self-injection locked diode laser and characterize its performance

Task #3: Develop and design the optimal optical and mechanical package for the 436 nm laser meeting the technical objectives of the effort



NASA Applications

High performance atomic frequency standards and clocks are an integral part of the NASA Deep Space Network responsible for communication, navigation, tracking, as well as related sciences. Performance attributes of atomic frequency references and clocks are stability and accuracy. For most applications, particularly in a two-way link architecture, only stability is required. For greater autonomy and strict one-way navigation system, an accurate clock (i.e. one with a precisely known rate) will be beneficial, as it does not need calibration.

Non-NASA Applications

Ultra-low phase noise and narrow linewidth lasers are useful for Oil and Gas exploration, pipeline monitoring, Smart Structures and border security sensing systems, atomic and molecular spectroscopy, LIDAR, coherent communications, and various other fiber optic sensing markets.

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

H9.01-8737 - Ultra-narrow bandpass filters for long range optical telecommunications at 1064nm and 1550nm

PI: Thomas Rahmlow

Omega Optical, Inc. - Brattleboro, VT



Identification and Significance of Innovation

Free space laser communication requires narrow bandpass filters with high on-band transmission and strong rejection of stray light and adjacent laser communication bands. The more narrow the passband, the better the signal to noise; however, the more narrow the band, the greater the concern for band shift due to operating temperature, angle of incidence, cone angle, near term environmental shift such as the absorption of water during pre-flight storage, and long-term shift due to changes in film structure related to aging, solarization, and radiation. We will develop and fabricate:

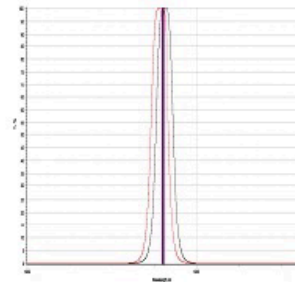
- Ultra-narrow (≤ 1 nm) bandwidth filter at 1064 and 1550 nm with high temperature stability and reduced sensitivity to cone angle.
- C-band filter sets (a 4 filter set in Phase 1 and a 20 filter set in Phase 2) with high off-band rejection.
- Testing required for space qualification.
- Laser targetted annealing to locally correct for non-uniformity.
- In-situ optical monitoring of ultra-narrow fabrication.

Estimated TRL at beginning and end of contract: (Begin: 3 End: 5)

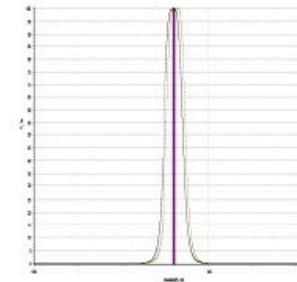
Technical Objectives and Work Plan

The program objective is to develop space qualified ultra-narrow laser line bandpass filter sets for long range laser communication. A set of 4 ultra-narrow (0.5 to 1 nm bandwidth) filters will be developed to pass 1 of 4 ITU laser lines while rejecting the other three with a minimum optical density of OD 4. These filters will operate over a temperature range of -90 to +80°C and exhibit no change in measured spectral performance following exposure to 10 day humidity, temperature influence cycling, 10 krad radiation exposure, and 40 g vibration testing.

The Phase 1 program is 6 months in duration and is comprised of 5 sub-tasks. Proof-of-concept will be demonstrated by fabricating two types of ultra-narrow (less than 1 nm FWHM) bandpass filters. The first filter type is a bandpass filter at 1064nm. The second bandpass filter demonstration is a set of 4 filters where each filter in the set passes a unique ITU C-band laser line while rejecting the other three laser wavelengths in the set with an attenuation of OD 4 or better. Fabricated filters will be evaluated for space qualification including humidity, temperature influence, radiation exposure, and vibration.



Modeled transmission of a 0.5 nm notch filter at normal and 2° AOI are plotted. The solid vertical line marks the laser wavelength. The filter is designed slightly long to accommodate angle shift.



Modeled transmission for a 0.5 nm notch filter for perfectly collimated and a 2° cone are plotted. The cone angle produces an effect shift in the transmission band.

NASA Applications

LIDAR, Free Space Communication, DWDM, Drones, AUVSI

Non-NASA Applications

LIDAR, Free Space Communication, DWDM, Drones, AUVSI, Autonomous vehicles (self-driving cars)

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

H9.01-8808 - Kilowatt Level Uplinks for Deep Space Optical Communications



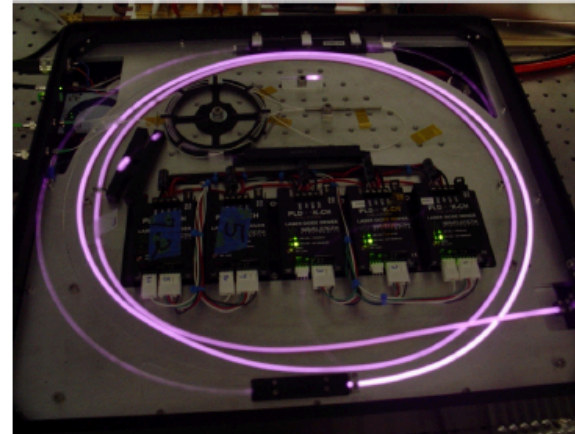
PI: Donald Sipes

Optical Engines, Inc. - Colorado Springs, CO

Identification and Significance of Innovation

Optical Engines will utilize its expertise in monolithic, microstructured high power pulsed fiber amplifier technology to develop and demonstrate an efficient, high power multi-element Transmitter capable of amplifying seed pulses to an average power of 500W at 20% duty factor for a peak power of 2500W with a pulse repetition frequency down in low data rate mode of 4kHz. In addition, there is a high data rate option with 120ns wide pulses and 5mj per pulse with Peak powers at 50kW.

- A line width stabilized pulsed seed source that suppresses periodic line narrowing for achieving the optimum line width that is stable.
- A multi-stage amplifier design with a double pass first stage with an integrated MZ modulator for pulse shaping and ASE limiting time gating.
- Gain Tailored core optimized Photonic Crystal Fiber (PCF) Coiled Fiber Laser with large High NA cladding that has been operated CW at 1.8 kW (pump limited) with no thermal modal instabilities.



Estimated TRL at beginning and end of contract: (Begin: 3 End: 4)

Technical Objectives and Work Plan

The goal of this Phase I program is for Optical Engines to develop and demonstrate the critical technologies as well as provide a complete transmitter design such that in a phase 2 program complete TRL 6+ uplink transmitters meeting all of the uplink requirements can be provided. Specifically, the Phase I technical objectives are:

1. Develop and Demonstrate a line width stable modulated and pulse shaped seed source that is immune to spontaneous line width narrowing
2. Using this seed source demonstrate a low data rate option (4kHz 20% DF that provides for 2500W of peak power and 500W Average power.
3. Investigate pulsed operation to the 5mj per pulse level in 120 ns pulses shaped for uniform amplification. Demonstrate this to over 250W Average power in a nested modulation format. Characterize stability under Max/Min PPM testing.
4. Provide a preliminary uplink transmitter design showing amplifier fiber design, I/O design, Packaging and thermal consideration, and array mounting and telescope interfacing.

NASA Applications

High peak power/ High Average power fiber based amplifiers will also have an application in LIDAR/ Remote Sensing techniques, which are continually seeking solutions that provide higher powers in the fundamental to create systems that have higher coverage, increased sensitivity and longer range than currently deployed systems.

Non-NASA Applications

Applications such as welding, cutting, drilling and micro machining will benefit substantially from improvements in performance with reductions in size, weight and cost offered from this technology development. These improvements will have a large impact in the automotive, aerospace, manufacturing, solar cell production, and medical device manufacturing in North America, Europe and in Asia.

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

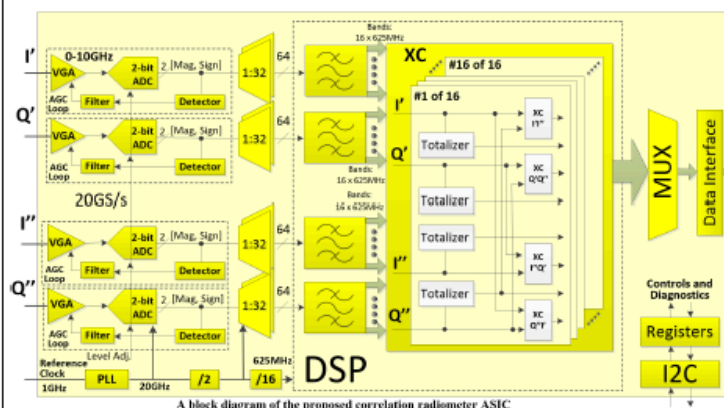
S1.03-9385 - Correlation Radiometer ASIC



PI: Anton Karnitski
Pacific Microchip Corporation - Culver City, CA

Identification and Significance of Innovation

Currently used correlating radiometers rely on analog signal processing, thus are bulky, power hungry and cannot be reprogrammable. Analog filter parameters, tend to be unstable over temperature, power supply voltage, may degrade over time and need tuning. The proposed low-power, rad-hard ASIC will operate with microwave correlation radiometer front ends down-converting the RF to up to 10GHz IF quadrature signals. The ASIC will digitize the incoming quadrature IF signals, will filter them splitting into up the into bands (up to 16), will cross-correlate the signals within each band and will ship out the resultant data in a convenient format. Instead of analog signal processing performing a strictly defined function, the ASIC will employ a digital signal processing (DSP) which can be reprogrammed to adopt specific parameters. A number of innovations will be introduced to the ASIC in order to combine programmability, low power consumption and radiation tolerance.



Estimated TRL at beginning and end of contract: (Begin: 1 End: 3)

Technical Objectives and Work Plan

The strategic project's Phase I objective is to prove ASIC's implementation feasibility. The specific objectives: 1. To develop the ASIC's architecture. 2. To validate the ASIC's architecture. 3. To select the CMOS technology for implementation. 4. To design the schematics of critical blocks. 5. To design the layouts of critical blocks. 6. To simulate/verify designed circuits. 7. To draw a conclusion regarding the feasibility of the ASIC's implementation. 8. To provide technical reports.

Work Plan: 1. Architecture level design 2. Architecture validation 3. Fabrication technology selection 4. Schematic design 5. Layout design 6. Design simulation/validation 7. Reaching the conclusion on project's feasibility 8. Project reporting

NASA Applications

- Remote sensing instruments for Earth, planet and sun exploration missions
- Radio astronomy
- Position synchronization between satellites in distributed and formation flying missions

Non-NASA Applications

- Remote sensing instruments developed by ESA and other space agencies
- Temperature, water vapor, pollutant and other exploration by EPA and NOAA
- Synthetic aperture radars for military applications and civil aviation
- Military surveillance satellites
- Thermal imaging for security systems
- Navigation satellites radiometers

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

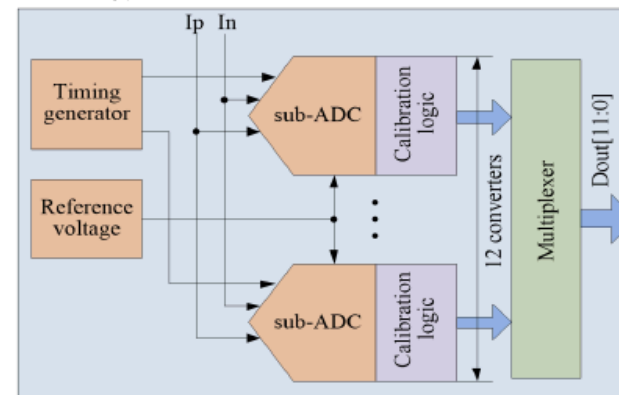
S1.04-8763 - A Low Power Rad-Hard ADC for the KID Readout Electronics



PI: Aliaksandr Zhankevich
Pacific Microchip Corporation - Culver City, CA

Identification and Significance of Innovation

Pacific Microchip Corp. will demonstrate the feasibility (Phase I) and will fabricate the prototypes (Phase II) of a radiation hardened ADC for the readout electronics of kinetic inductance detectors (KIDs). KIDs are developed for photometers and spectrometers required for astrophysics focal planes, and Earth or planetary instruments. The novel ADC will combine high radiation hardness with low power consumption. The ADC will feature a 12-bit resolution at the 1GSps rate, the tolerance to the TID of at least 4Mrads and increased immunity to the SEE. A novel technique for time interleaving and calibration of the capacitor mismatch will be introduced. The ADC will be implemented based on an ultrathin gate oxide 28nm CMOS technology for low power consumption and increased TID tolerance.



Block Diagram of the proposed analog-to-digital converter

Estimated TRL at beginning and end of contract: (Begin: 1 End: 2)

Technical Objectives and Work Plan

The strategic objective of Phase I is to demonstrate the feasibility of implementation of the radiation hardened, low power ADC which will meet the NASA's requirements for the application in the KID's readout electronics. The specific objectives include: to provide the architecture of the low power radiation tolerant ADC; to employ the time interleaved technique for increasing the sampling rate; to use the sub-ranging technique, an asynchronous SAR and the novel calibration technique to reduce the switching power; to develop the comparator with a preamplifier and the low-stress bootstrapped switch to increase linearity.

Work Plan:

- Block level design
- Technology selection
- Critical circuit design and verification
- Layout design
- Conclusion on implementation feasibility
- Reporting

NASA Applications

- Space based sensors and detectors
- Space and Earth-based radar applications
- Digital beam forming (DBF) systems

Non-NASA Applications

- High-energy physics instruments
- Communication and scientific satellites
- Advanced synthetic aperture radars (SARs)
- Instrumentation at nuclear facilities

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

S2.01-9936 - Polymer Coating-Based Contaminant Control/Elimination for Exo-S Starshade Probe



PI: James Hamilton

Photonic Cleaning Technologies, LLC - Platteville, WI

Identification and Significance of Innovation

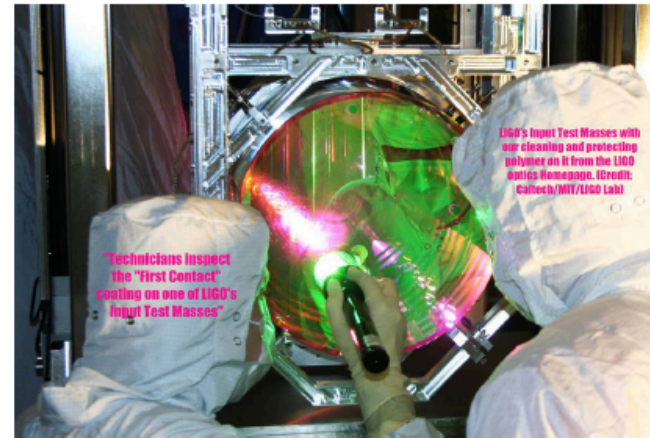
The Exo-S Starshade Probe's planned mission would identify exoplanets using an occlusion device (the "Starshade") to block starlight from entering a telescope. To avoid solar glare and scatter interference its edges must be razor-sharp and exceedingly clean (i.e., a few 100 micron dust particles on an edge scatters light comparable to the signal of an exoplanet). Photonic Cleaning Technologies (PCT) proposes to develop a novel pourable, peelable, low adhesion, residueless polymer coating that will clean and protect the Starshade's edges from manufacture to launch. We will demonstrate feasibility in this Phase I SBIR by formulating a polymer blend/solvent blend that maximizes cleaning and minimizes adhesiveness on the amorphous metal alloys to be used in the Starshade's edges. PCT's current product residueless strip coating has cleaned sensitive surfaces like the Hope Diamond, optics on meter class telescopes like WM Keck (Mauna Kea) and GTC (La Palma) and was an enabling technology for nd Lockheed's Thaad Ballistic Missile System and LIGO, the Laser Gravity Wave Observatory.

Estimated TRL at beginning and end of contract: (Begin: 2 End: 4)

Technical Objectives and Work Plan

Obj. 1: Develop, test, & identify polymer blends/solvent blends (PB/SB) with enhanced cleaning efficacy/reduced adhesion when used on the Starshade edge alloys. We will develop 3 new polymers and 3 new 50/50 polymer blends (PB=6). We will combine each PB with 3 known SBs for 18 total PB/SBs. In our clean room, we will apply each PB/SB to coupons of glass, Al, Cu, and MBF23 Ni/Fe or similar alloy. We will compare adhesion strength & surface cleanliness to each other and to our current commercial product. **Goal:** The lead PB/SB will show at least 50% less film adhesion to Ni/Fe alloys to our current product, and leave no particles larger than 30 nm on the surface. If multiple PB/SBs meet these metrics, the lead PB/SB will use the least expensive materials.

Obj. 2: We will write Standard Operating Procedures (SOP's) and practical engineering procedures. Because products developed via SBIR are intended for NASA's use to fulfill its missions, clear, concise, and detailed SOPs are required. The SOPs will instruct personnel in the usage that minimizes potential damage or recontamination of the Starshade's edges. SOPs will be evaluated for clarity and tested for accuracy by untrained personnel. **Goal:** Using the SOPs, untrained personnel will be able to correctly (>0.05% errors) apply/remove the polymer to MBF23 coupons without damage while also achieving the cleanliness goals from Obj. 1.



NASA Applications

The stripcoating developed will provide superior cleaning & protection from recontamination for the Starshade's edges & most other technologically-important surface materials through the entire prelaunch path, regardless of structural complexity, size, or sensitivity of exposed components. Potential future applications include creating/maintaining sterile & biological contamination-free surfaces, electrostatic-free films, cleaning up and sequestering of radioactive contamination as well as "space preparation" of bulk metallic glass (CMG) gears.

Non-NASA Applications

Post-SBIR commercialization will focus on markets where surface sterility is of interest. These include medical & scientific research, pharmaceutical & food productions, or any manufacturing currently using clean rooms to maintain sterility. Surface radiation contamination removal would interest government & commercial operators within the nuclear/defense industries.

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

S4.05-9760 - Antimicrobial Coating for Metallic Surfaces

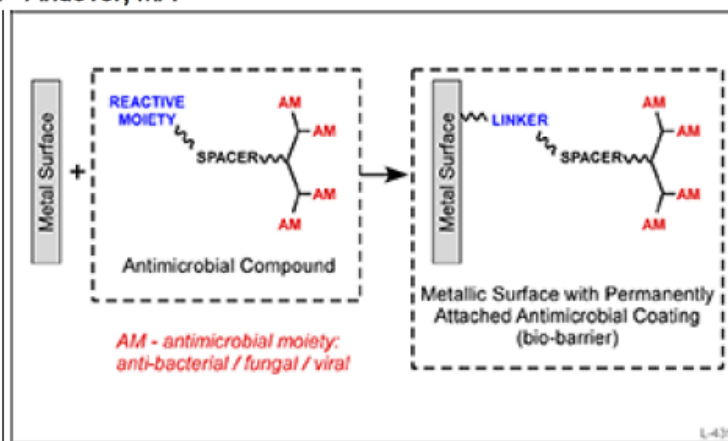


PI: Dorin Preda

Physical Sciences, Inc. - Andover, MA

Identification and Significance of Innovation

NASA needs innovative technologies to protect biological sensors and to prevent contamination of extraterrestrial bodies. Physical Sciences Inc. (PSI) will develop novel broad spectrum antimicrobial (anti-bacterial/fungal/viral - ABFV) coatings for the exposed surfaces of spacecraft metals, plastics, and electronics that will act as a bio-barrier to prevent both forward and backward contamination. The technology will offer a complementary and milder approach to the current, energy intensive sterilization methods that only provide a one-time decontamination. The PSI approach is a permanent coating that will prevent inadvertent contamination throughout the spacecraft assembly and integration. In Phase I, PSI will synthesize ABFV compounds that permanently attach to the surface of metallic materials and demonstrate high ABFV efficacy of the treated surfaces and compatibility with current sterilization processes. In a potential Phase II, PSI will further demonstrate the technology at a scale relevant to spacecraft applications and extend its use to other spacecraft hardware materials.



Estimated TRL at beginning and end of contract: (Begin: 2 End: 4)

Technical Objectives and Work Plan

Technical Objectives

- Develop process to attach the antimicrobial compound to metallic surfaces such as aluminum and stainless steel.
- Demonstrate high antimicrobial efficacy (>99.99% kill, or >4-Log reduction) against a broad spectrum of pathogens (bacteria, fungi, viruses).
- Demonstrate robustness of the antimicrobial treatment under several sterilization conditions (DHMR conditions, vapor hydrogen peroxide and gamma irradiation). The resulting surfaces will maintain good ABFV efficacy (<0.5-log reduction).

Work Plan:

During the proposed Phase I program, PSI will:

- Develop a process for AM compound attachment to aluminum, anodized aluminum and stainless steel.
- Evaluate the antimicrobial efficacy of the coated materials against a panel of pathogens (bacteria, fungi and viruses).
- Evaluate the antimicrobial activity before and after sterilization treatments (DHMR, vapor hydrogen peroxide and gamma irradiation).

NASA Applications

The proposed technology will have NASA applications to both interplanetary and manned spaceflight markets. NASA is planning a wide range of extra-terrestrial missions and has the responsibility not to introduce bacteria or viruses from earth into pristine extraterrestrial bodies. Manned platforms require high internal humidity which leads to rampant bacterial and fungal growth on surfaces. The PSI process will reduce the cost of the spacecraft processing facilities, the integration times, and the need for frequent decontamination procedures.

Non-NASA Applications

The proposed technology will have applications in the medical, pharmaceutical, military, and first responder industries. The technology will reduce the incidence of operating theater contamination and the costs of treating post-operative infections and prevent contamination during the drug manufacturing. Military applications include defeating bio warfare agents and self-decontaminating gear.

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

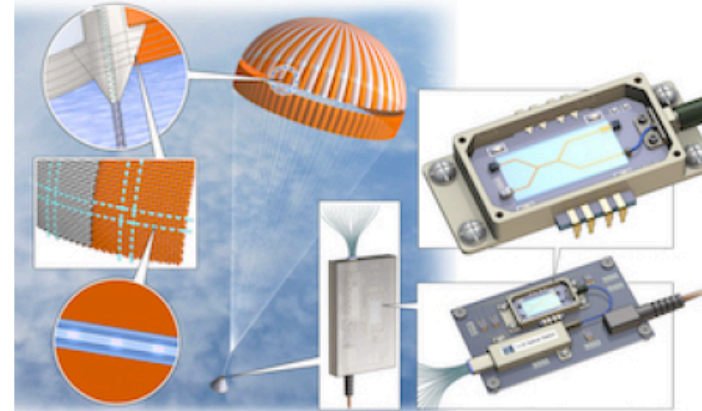
Z7.01-8404 - weaved distributed plastic optical fiber sensor (DIFOS) SHM system



PI: edgar mendoza
Redondo Optics, Inc. - Redondo Beach, CA

Identification and Significance of Innovation

NASA Entry, Descent and Landing Systems has a need for innovative embeddable sensor technologies of the order of the textile fabric equipped with low weight and self- power time synchronized data collection systems that can monitor structural loads across the large decelerator – parachute and ballute – structures. Redondo Optics proposes to develop and demonstrate to NASA a no-moving- parts, miniature size, light weight, self-powered, and wireless communication weaved plastic optical fiber sensor (DIFOS) SHM system suitable for the time- synchronized distributed monitoring of passive and dynamic loads/stress/strains within the fabric and strands of large and entire cross-sections of NASA's supersonic (DBG) decelerator systems such as parachutes and ballutes.



Estimated TRL at beginning and end of contract: (Begin: 2 End: 4)

Technical Objectives and Work Plan

The success of the Phase I program will be accomplished through the execution of the following key objectives:

Objective 1. Select suitable plastic optical fibers (POF) with mechanical compliance to supersonic parachute broadcloth fabric materials.

Objective 2. Develop methods for weaving selected high performance POF sensors within broadcloth fabrics used in parachute structures

Objective 3. Produce test coupons of the "Smart" parachute broadcloth fabrics with the weaved POF sensors and use these to conduct axial and bi-axial stress tests

Objective 4. Assemble a laboratory prototype of a light weight, compact, self-power, and wireless data communication OFDR DIFOS™ transceiver sensor interrogation system

Objective 5. Demonstrate the mechanical properties of the DIFOS™ instrumented "Smart" parachute broadcloth fabrics under simulated inflation events

Objective 6. Preliminarily establish the commercialization promise of the proposed DIFOS™ technology. Identify potential strategic commercialization partners that will assist ROI with the transition of the DIFOS™ technology to a parachute decelerator platforms during Phase II and Phase III of the program.

NASA Applications

All of NASA's current and future space vehicle programs will benefit significantly from this project. Specific NASA applications of the propose DIFOS SHM system include decelerator systems – parachutes and ballutes, honeycomb structures, multi-wall pressure vessels, thermal blankets, meteoroid shields, batteries, etc., commonly found in spacecraft, and habitats, and support infrastructures.

Non-NASA Applications

Specific industries that will benefit from this program and the EFISense system include the aerospace and aviation industry, oil & gas and petrochemical industries, wind turbines, utilities, coal – gas – and nuclear power and water treatment plants, automotive, seaports, warehouses, military facilities, airports, civil engineering construction, and healthcare.

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

S4.01-8340 - An Enhanced Modular Terminal Descent Sensor for Landing on Planetary Bodies

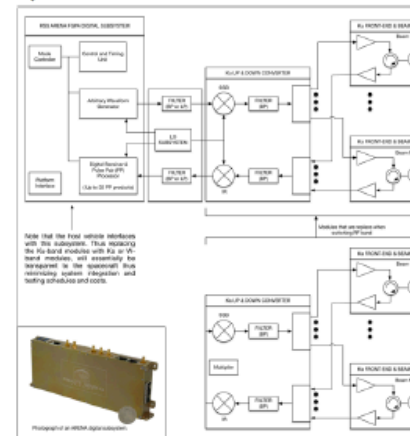


PI: James Carswell

Remote Sensing Solutions, Inc. - Barnstable, MA

Identification and Significance of Innovation

- Provide a sensor design to measure terrain-relative translational state that is robust to dust and expands the envelope of operation.
- Design a reproducible, capable, and relatively small sensor, we will help enable all classes of future missions.
- By extending the sensor capabilities beyond that of MSL-TDS, overcoming problems of dust, sand, and airborne particles, we will enable precision landing to at least the levels of MSL, if not beyond.
- Our modular design will feed forward into systems that require even greater sensitivity.



Estimated TRL at beginning and end of contract: (Begin: 1 End: 3)

Technical Objectives and Work Plan

1. Provide a sensor design to measure terrain-relative translational state based on MSL-TDS requirements
 - robust to environmental dust/sand/illumination effects with a Ku-band design and increased sensitivity
 - Extend the dynamic range over which measurements are collected
2. Reduce the external processing needed by the host vehicle
3. A modular, reproducible configurable innovative sensor for EDL operations including Earth's moon, Mars, Venus, Titan, Europa
 1. Sensor design including RF system analysis, modular backend and performance trade-offs
 2. Low sidelobe antenna design
 3. Pulse-versatile robust design for multiple descent profiles
 4. Path to space-qualification and reproducibility assessment
 5. Final Report/Phase II proposal for prototype

NASA Applications

The TDS would satisfy NASA's needs for a reproducible, low-cost landing radar system for upcoming landing missions, including Discovery class through flagship concepts like a Europa lander. The TDS sensor solves a key, critical long term NASA need post-Mars2020, enabling numerous classes of planned and future robotic and crewed missions.

Non-NASA Applications

A key technology to enable private space exploration will be a cost effective, reconfigurable landing system for these platforms. In addition to Earth returning launches, the United States, European, China and other governments are planning missions to the Moon, Mars and other planets and bodies. A space qualified Ku-band landing system would have immediate applicability to these efforts.

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

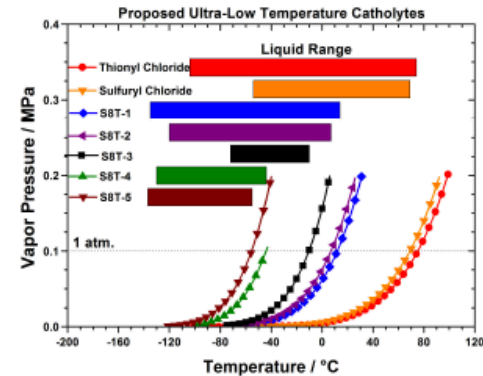
S3.03-9828 - Liquefied Gas Catholytes for Ultra-Low Temperature Lithium Primary Batteries



PI: Cyrus Rustomji
South 8 Technologies, Inc. - San Diego, CA

Identification and Significance of Innovation

State-of-art lithium primary batteries may operate down to -80 C, however, many of NASA's mission requirements, including those for Ocean Worlds, require energy storage devices at -100 C or lower. South 8 Technologies proposes the use of "Liquefied Gas Catholytes for Ultra-Low Temperature Lithium Primary Batteries". These catholytes are gaseous under standard conditions, but may be liquefied under mild pressures, showing exceptionally low melting points, very low viscosities and relatively high dielectric constants, allowing for ultra-low temperature operation of Lithium Primary Batteries. South 8 Technologies believes the technology proposed will enable energy storage at temperatures as low as -140 C, whereas the state-of-art allows operation is limited to -80 C. High temperature operation will be similar with operation limited to about +60 C. Further, the energy density of the active cathode material may be increased by as much as 30%. Voltage delay, a reoccurring issue in lithium primary batteries, may be reduced as well.



Estimated TRL at beginning and end of contract: (Begin: 2 End: 4)

Technical Objectives and Work Plan

The primary goal of this SBIR Phase I effort will be to demonstrate an operational lithium primary battery as low as -140 C. Beyond that, operation up to +60 C, an increase in energy density and lowering of the voltage delay of the primary battery system are desirable. Expected TRL 4 by end of Phase I work.

Technical Objectives:

1. Demonstrate lithium metal stability in proposed catholytes solutions
2. Demonstrate electrolytic conductivity of >1 mS/cm at -100 C
3. Demonstrate operation of Li-Primary battery from -140 to +60 C
4. Demonstrate an increase in energy density and lowering of voltage delay
5. Chemical and morphological characterization of electrodes
6. Mechanical model for full form-factor cell development

Work Plan:

Custom measurement equipment has already been developed to handle the proposed high pressure catholyte systems. Tool sets developed include electrolytic conductivity measurement apparatus and coin-cell measurement systems and catholyte cell filling equipment. All materials are rated for high pressure and are chemically compatible with the proposed materials.

NASA Applications

Electrochemical energy storage devices are critical to many of NASA's missions. Low temperature energy storage is critical in Ocean Worlds explorations, including Europa, Enceladus, Titan, Ganymede, Callisto, Ceres. Particularly, topic S3.03 of the solicitation calls for "advanced primary and secondary battery systems capable of operating at temperature extremes from -100 C for Titan missions". Further, topics S4.04 (Extreme Environment Technology) and Z1.02 (Surface Energy Storage) can benefit from the Ultra-Low Temperature Battery Technology.

Non-NASA Applications

While there is not a large market for primary batteries with ultra-low temperature operation below -80 C, an increased energy density and/or cell with higher power capabilities may find use in military applications where a long shelf life and high power, high energy density are required. Development of high-atmosphere drones and balloons (-70 C) are increasingly more common for telecommunications.

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

Z3.02-8909 - Thermoplastic forming of bulk metallic glasses for precision robotics components



PI: Evgenia Pekarskaya
Supercool Metals, LLC - New Haven, CT

Identification and Significance of Innovation

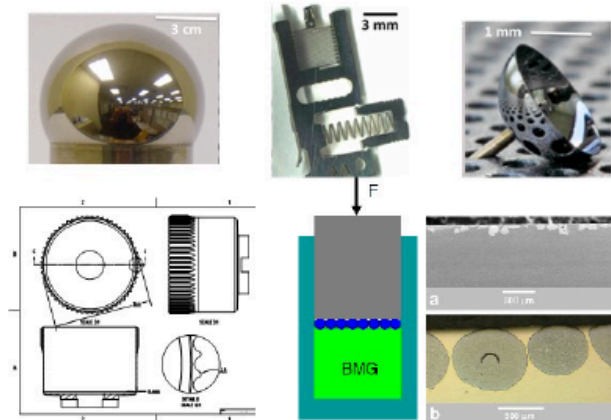
We propose to utilize the unique thermoplastic forming (TPF) ability of bulk metallic glasses (BMGs) to net shape precision robotic gears for extremely low temperature environments. Specifically, we will focus on thin walled components with high dimensional accuracy and surface smoothness. Until recently, processing of BMGs has been a major challenge due to the requirement for rapid cooling. Supercool Metals is developing TPF methods that allow forming of BMGs similar to plastics. We have demonstrated net shaping with highest precision on length scales from sub-nanometer to several centimeters and achieved surface finish with subnanometer roughness. The proposed fabrication method will yield shapes and accuracies that can't be achieved with any other metal fabrication process, far beyond machining and casting methods. We will also explore novel methods to fabricate composite surfaces to further improve friction properties of gears. This paradigm-shifting technology will push the boundaries for metallic materials, expand NASA's capabilities and impact structural applications overall.

Estimated TRL at beginning and end of contract: (Begin: 3 End: 4)

Technical Objectives and Work Plan

Objectives of the current project are closely aligned with NASA's goals in the Advanced Manufacturing area. For Phase I, we intend to net shape a flexspline component for a harmonic drive gear. The project will serve as a demonstration of TPF capabilities with BMGs for fabrication of complex robotic gears, including those with thin walls and high surface smoothness that require no post-machining.

To achieve this goal, we plan the following R&D activities. We will first develop a processing map with the BMG alloy specific processing requirements for a high aspect ratio components. Based on these maps, we will design different molds and fabricate a flexspline part for a harmonic drive gear used in high precision robotics. We will perform structural characterization of components to ensure amorphous structure and to evaluate thermal processing budget. BMG components have shown potential to be used without lubricants in robotics gears at extremely low temperatures, which is highly attractive for NASA missions. We propose to further enhance friction and wear behavior by exploring novel methods to fabricate composite surfaces with molybdenum disulfide particles. The current project will result in BMG flexspline prototypes with challenging geometries, superior mechanical properties, enhanced friction and wear behavior, and lower cost than components produced by casting methods.



NASA Applications

NASA's Advanced Manufacturing Program highlights the need for innovative methods for net shaping of bulk metallic glass components with thin walled structures and high dimensional accuracy. In this project, we focus on forming precise robotics components using BMGs. BMG robotics components are highly attractive for use at low temperature and harsh environments (such as Europa mission) due to improved mechanical properties and ability to operate unlubricated. BMG technology is also attractive for small satellites and pressure vessels.

Non-NASA Applications

Combining the properties of best structural metals with the processability of thermoplastics brings unique opportunities to robotics, aerospace, defense, automotive and biomedical industries. Specific applications that we are addressing in this NASA Phase I project include precision robotics components that outside space can be used for industrial and consumer applications.

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NON-PROPRIETARY DATA

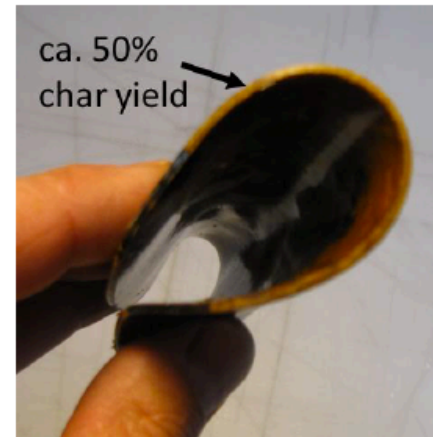
NASA SBIR/STTR Technologies
Z2.01-9104 - Thermal Insulator for a Venus Lander



PI: Michael Diener
TDA Research, Inc. - Wheat Ridge, CO

Identification and Significance of Innovation

A lander on the surface of Venus is heated by the 460 °C surface temperature, which, even with the best current designs using passive insulation, cause its electronics to fail in much less than a day. Active cooling concepts are not only exceedingly heavy but also exceedingly inefficient. TDA proposes a new insulation for the exterior of the lander that incorporates heat rejection mechanisms that apparently have not been previously considered for the Venus surface. Our insulation will make use of a flexible material that has been recently developed at TDA (shown in the image), and we will compare it to other potential but brittle insulations. Order-of-magnitude calculations suggest that the lifetime of the lander can be extended from hours to days.



Estimated TRL at beginning and end of contract: (Begin: 1 End: 3)

Technical Objectives and Work Plan

The Phase I work plan begins with the screening of candidate materials in our thermogravimetric analyzer (TGA) at 460 °C in CO₂. In some cases, we will synthesize materials that are not commercially available, but, based on previously obtained data, are expected to have outstanding potential use as a Venus ablator. No de novo syntheses are proposed. The most promising materials will then be formed into composites using methods that are appropriate for their specific chemistry and materials challenges. While these steps are occurring, we will build a simple heated pressure vessel for observing the performance of large (several inches in diameter) specimens of the best compositions at higher pressures of CO₂. Finally, selected mechanical properties of promising composite compositions will be determined in order to demonstrate their ability to survive mechanical loads during launch and landing.

NASA Applications

The insulation will be designed for a Venus lander. However, the materials and techniques developed during this project are potentially useful for a wide range of thermal protection systems (TPS), and could potentially be redesigned for use in applications such as (re-)entry heatshields, both deployable and static.

Non-NASA Applications

Thermal protection is also of substantial interest for a host of military applications, primarily including re-entry heatshields, rocket nozzles and internal insulation for solid rocket motor cases.

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

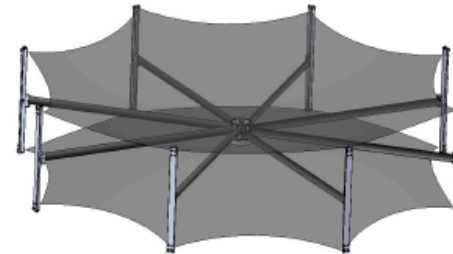
S1.02-9250 - Enabling Larger Deployable Ka-Band Antenna Apertures with Novel Rib



PI: Gregg Freebury
Tendeg, LLC - Louisville, CO

Identification and Significance of Innovation

The significance and relevance of the proposed innovation is to design and develop a novel rib that will enable 2-4m aperture parabolic reflectors and antennas for smallsats. The rib will be rollable and allow 100:1 compaction ratios. It will provide deployment authority and deployed structural integrity meeting Ka-band precision requirements. Higher communication data rates, longer transmission distances, increased sensor capacity for active radar and radiometers are all directly related to larger aperture sizes.



Estimated TRL at beginning and end of contract: (Begin: 2 End: 3)

Technical Objectives and Work Plan

Specific goals of phase I include:

- Define unique requirements for the ribs at various aperture sizes
- Perform a rib geometry trade study comparing double omega vs. slit tube vs. lenticular cross sections with and without shear features
- Perform material trade studies for rib construction
- Design optimized reflector interface features for each configuration
- Perform finite element analysis to determine system performance of the rib during deployment and fully deployed
- Characterize the packaging performance and buckling capacity of a LaRC mini-CTM rib

NASA Applications

The proposed innovation relative to NASA needs will be focused on small aperture antennas used for Earth observing science missions (RainCube radar, radiometers), deep space communications, and any mission needing high data rate downlinks. The rib technology would enable larger apertures for any higher gain mission needs.

Non-NASA Applications

There is strong market growth in CubeSat up to smallsat size satellites in the commercial arena. Numerous communications, data transfer and Earth observation constellations are planned. Many of them would benefit from a lightweight, small packaged volume, high gain antenna. In the terrestrial market, the U.S. Military is seeking man-packable high gain antennas for forward operating Warfighters.

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

S2.02-8520 - Redundant StarShade Truss Deployment Motor/Cable Assembly



PI: Neal Beidleman
Tendeg, LLC - Louisville, CO

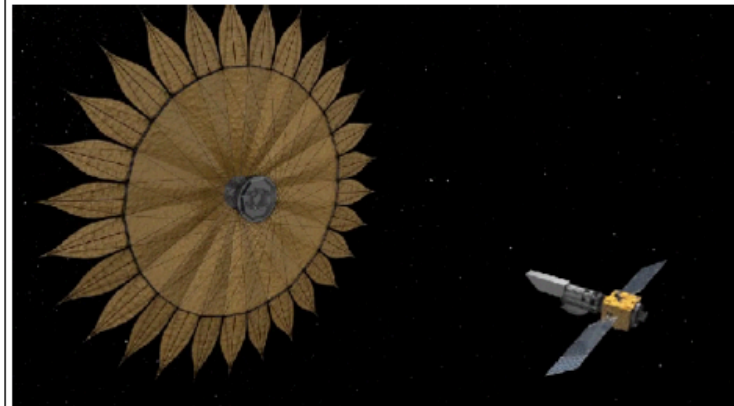
Identification and Significance of Innovation

The proposed innovations are as follows:

1) A fully redundant electrical and mechanical motor/cable deployment assembly 2) A redundant motor/cable deployment assembly that is integrated and deploys a perimeter truss for a starshade.

The significance and relevance of the proposed innovations is to meet the technical challenges of deploying a large scale perimeter truss (10-30m diameter) for a starshade.

The STD's "Exo-S Final Report" identified an open issue to "Mature perimeter truss technology readiness." This is part of a defined starshade technology gap S-5 that is titled "Demonstrate inner disk deployment with optical shield." In the NASA JPL starshade design the petals are placed into their precise position by the deploying truss. The truss also deploys the spiral wrapped inner disk and at the end tensions the precision spokes. If the truss was not able to fully deploy or meet the on-orbit load (deployment and deployed) and positioning requirements then the mission would fail.



Estimated TRL at beginning and end of contract: (Begin: 2 End: 5)

Technical Objectives and Work Plan

The overarching objective of the Phase I program is to develop a prototype motor & spooler assembly that can be shown to work with a truss deployment structure such as Starshade. Tendeg will design, analyze, manufacture, and test a fully integrated motor/cable assembly. Two units will be built. One of the units will be delivered to JPL for use in their laboratory environment.

The specific goals of Phase I are:

- Detailed design of a truss deployment system for use on the Starshade truss or similar mechanism.
- Understanding the performance parameters of the design under representative condition using analysis and simulation (achieve TRL 3)
- Manufacture of 2 similar prototype units
- Validation of performance of a medium fidelity prototype in a relevant environment with representative supports (achieve TRL 5)

Creation of a complete drawing package to proceed to flight level build and qualification (prepare for TRL 6)

NASA Applications

Technology developed during this SBIR program will be directly applied to any NASA telescope program involved with exoplanet discovery and characterization that needs an external occulter, or Starshade. NASA has identified a potential rendezvous mission with WFIRST/AFTA because it is a large astrophysics telescope capable of supporting direct imaging with a starshade.

The technology developed would apply to any cable driven deployment that would benefit from the reliability of a fully redundant electrical and mechanical

Non-NASA Applications

Beyond starshades and ring truss deployables, the technology developed through this SBIR would apply to any cable driven deployment that would benefit from the reliability of a fully redundant electrical and mechanical system. Cable spoolers are used for deploying articulating booms, trusses, thermal blankets, solar arrays as well as deploying and controlling guys and stays.

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

Z6.01-8473 - Robust Multicore Middleware



PI: Ian Troxel
Troxel Aerospace Industries, Inc. - Gainesville, FL

Identification and Significance of Innovation

- Current and emerging spaceflight processors leveraging heterogeneous multicore/co-processor architectures to satisfy the ever increasing onboard processing demands required by planned NASA missions
- Potential to increase processing bandwidth, power efficiency, and fault tolerance for onboard processing applications
- All proposed NASA missions requiring autonomy or massive data reduction can benefit
- However, incurs increased hardware and software complexity, development cost, and radiation susceptibility
- Troxel Aerospace proposes to develop a robust middleware management technology for spacecraft-focused multicore/co-processor processing devices
- Enable a fault tolerant, resources manager transparent to mission applications executing upon the middleware
- Provide a standardized, intelligent resource, fault, and power management interface.

Estimated TRL at beginning and end of contract: (Begin: 2 End: 3)

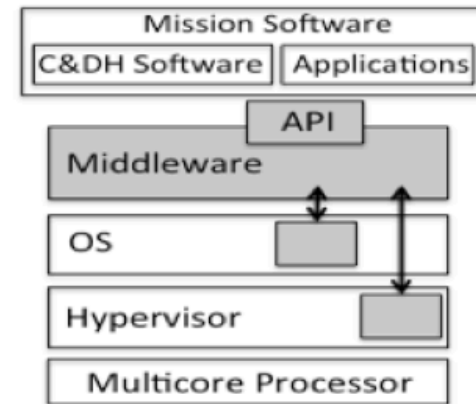
Technical Objectives and Work Plan

Technical Objectives:

- Define requirements by solidifying desired capabilities and operating environment with NASA support
- Develop baseline features and analyze its viability

Work Plan:

- Define multicore/co-processor middleware requirements and capabilities
- Develop baseline middleware architecture and features
- Undertake middleware analysis and perform project review
- Develop future phase plan and final report



NASA Applications

- All missions that need more reliability, autonomy, and commonality across spaceflight processing systems
- Long-duration crewed missions, space-based observatories, and solar system exploration
- Near-Earth Asteroids (NEAs), extreme science, and deep space missions
- Entry, descent, and landing, and high-data-rate instrument throughput
- Pinpoint landing, hazard avoidance, rendezvous-and-capture, and surface mobility

Non-NASA Applications

- Government agencies requiring onboard processing (e.g. NRO, DoD, DoE, SMC)
- Commercial space: Telecom, imagery, launch vehicles, and exo-planetary ventures
- Smallsat: increased fault tolerance is of greatest concern
- Terrestrial: medical radiation, aircraft, automobile, and public transportation

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

S4.03-8399 - Advanced Ignition System for Hybrid Rockets for Sample Return Missions



PI: Arthur Fortini
Ultramet - Pacoima, CA

Identification and Significance of Innovation

To return a sample from the surface of Mars or one of the larger moons in the solar system will require a propulsion system with a comparatively large delta-V capability due to the magnitude of the gravity well. Consequently, a significant propellant mass will be required. A recent study has shown that bringing the propellant from Earth in the form of a hybrid rocket with multi-start capability is a mass-competitive option that trades more favorably than either a CO₂ electrolysis system or a bipropellant system where the propellants are generated on Earth. Using a high-performance hybrid propellant combination and being able to restart the hybrid rocket are the keys. This project will focus on developing a robust electrical heater that can heat the oxidizer flow to temperatures above autoignition, thus enabling reliable restart capability.



Estimated TRL at beginning and end of contract: (Begin: 3 End: 4)

Technical Objectives and Work Plan

Phase I will focus on the use of electrically heated foam to bring a portion of the oxidizer flow to the desired temperature. In Phase II, a heater will be added to the fuel grain. Modeling and testing have shown excellent heat transfer between the foam and a fluid moving through it, so the first task will be to apply the model to a specific mission. Although the SiC foam used for the heater is oxidation-resistant, a protective oxide coating will be applied to improve its performance in the presence of hot O₂ or N₂O₄. Electrical attachments to the foam will also be addressed in terms of their mechanical robustness and oxidation resistance. Basic function testing will be performed to validate the model and measure the electrical power and foam volume required to achieve a given temperature with a given oxidizer. Ignition testing will then be performed with paraffin to verify the performance of the system and to map the oxidizer temperature required for ignition as a function of the paraffin temperature.

NASA Applications

The near-term applications are igniters for restartable hybrid rockets for sample return missions from Mars or the larger moons in the solar system. More generally, oxidation-resistant high temperature foam-based heaters are propellant-agnostic and can be used as igniters for any non-hypergolic propellant combination (e.g. O₂/CO, LOX/CH₄, LOX/ethanol, and LOX/RP-1; N₂H₄, LMP-103S, and the E, Q, and A blends of AF-M315). The technology is applicable to engines of virtually any thrust class.

Non-NASA Applications

This ignition technology can be used in main and attitude control engines on spacecraft, and main and reaction control engines on boosters. Other applications include air heaters for hypersonic wind tunnels, ignition systems and catalyst preheaters for aeropropulsion turbine engines and turbine engines used for terrestrial power generation, and high-efficiency heaters.

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

S1.09-9809 - SmallSat Stirling Cryocooler for Earth Science and Interplanetary Exploration



PI: Carl Kirkconnell
Wecoso LLC - Huntington Beach, CA

Identification and Significance of Innovation

- High frequency (>300 Hz), compact, high efficiency Stirling SmallSat Cryocooler (SSC)
- "Post-Oxford" motor design leapfrogs all competing efforts
- Enables high resolution MWIR and LWIR imaging on SmallSats
- Immediately applicable for 70K to 180K applications and extensible down to 30K w/ multi-stage variants
- Inherently low exported disturbance
- Implemented using Additive Manufacturing techniques to meet unique, miniaturized geometric requirements for structure and regenerator
- Novel "Inherently Low Ripple" (ILR) motor drive electronics for SSC, implementing a new digital architecture scalable for any size Stirling or pulse tube cryocooler
- World class proposal team: West Coast Solutions, Georgia Tech, and Creare
- Phase III Commercialization Plan through Creare fully defined



SmallSat Stirling Cryocooler

Key Metrics

- 400mW @ 80K for 6.1W DC
 - Trej = 300K
- TMU Mass < 100g
- CCE Mass < 50g

Estimated TRL at beginning and end of contract: (Begin: 2 End: 3)

Technical Objectives and Work Plan

Technical Objectives

1. Thermodynamic design of complete Stirling cryocooler
2. Cold head manufacturing plan implementing Additive Manufacturing (AM)
3. Moving mechanism concept design for compressor and expander
4. Proof of Concept simulation and experiment for Inherently Low Ripple motor drive

Work Plan

1. Georgia Tech to implement their proven "in tandem" REGEN / Sage / Fluent modeling approach
2. Perform manufacturing trade studies to identify best method(s) by which to realize the target geometry
3. Leverage past microcompressor work, finite element magnetic field simulation, and solid modeling to define moving and sealing mechanisms for the compressor and Stirling warm end
4. Simulate the ILR digital design in MATLAB and then test it using an evaluation board

NASA Applications

- Low Earth Orbit (LEO) SmallSat infrared sensing satellites (MWIR, LWIR, hyperspectral, multispectral, etc.)
- Interplanetary infrared sensing satellites (Europa, Mars, Venus, etc.)
- Planetary exploration vehicle-mounted imagers (Mars Rover and follow-ons)
- Digital ILR scalable for any size linear cooler electronics, extending the applicability of this research to virtually any actively-cooled cryogenic payload

Non-NASA Applications

- Department of Defense Earth-imaging satellites
- Infrared imaging of resident space objects
- Launch monitoring and success verification
- Commercial constellations of infrared imaging satellites

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

S2.04-9520 - Battery-Powered Process for Coating Telescope Mirrors in Space



PI: David Sheikh

ZeCoat Corporation - Torrance, CA

Identification and Significance of Innovation

ZeCoat Corporation will develop a battery-powered, aluminum deposition process for making broadband reflective coatings in space (wavelength range: 30-nm to 2500-nm). The process uses an array of evaporation filaments powered by batteries. The vacuum coating process is scalable for large mirrors several meters in diameter, but is applicable to any size mirror. By placing iridium (or a multi-layer interference coating) on the mirror initially (coated on earth), followed by a fresh coat of aluminum in space, the broadband response of the telescope could be extended down to 30-nm. Current coating technologies limit the reflectance response to 90-nm because of the absorbing fluoride coating which protects the aluminum from oxidation on earth. To achieve future wavefront requirements over a large primary mirror, it is likely that many evaporation sources will be required.

In Phase I, we will demonstrate feasibility of the process. In Phase II, miniaturized battery-powered units will be designed and manufactured, and the coating process tested in a simulated space environment.

Estimated TRL at beginning and end of contract: (Begin: 3 End: 4)

Technical Objectives and Work Plan

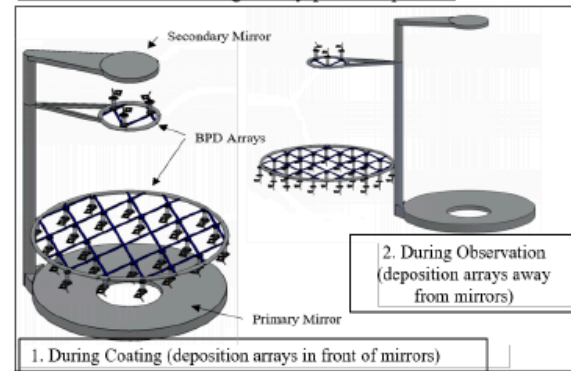
Objectives

- Demonstrate the feasibility of making a high UV reflective aluminum coating by a battery-powered filament evaporation process in a simulated space environment
- Demonstrate an aluminum over-coated iridium reflective coating design
- Demonstrate the feasibility of using LiFePO₄ (or other battery chemistry) in a simulated space environment after relevant thermal cycling
- Define mathematical solutions for creating flat coatings, which minimize wavefront error, using evaporation plume data and an array of filaments
- Validate the math models by demonstrating uniform coatings, measured over large areas, with minimal impact on WFE.

Tasks

- NRE- experimental design, documentation
- Prepare pre-melted aluminum filaments
- Battery trade study
- Fabricate iridium-coated mirrors
- Map the plume and use computer model
- Passivate aluminum with ionized NF₃
- Coat subscale mirror
- Design miniaturized BPD unit

Sketch of how a large coating array might be deployed for coating and for observations using battery-powered process



NASA Applications

- Coating mirrors in space for broadband mirrors into the EUV
- Repair of coatings in space
- Coating FUV-quality aluminum large mirrors on the ground for use in space

Non-NASA Applications

- High-quality UV-aluminum coatings for large ground-based mirrors
- Coatings for large aircraft simulator mirrors

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

S2.01-9865 - Technology Development for High-Actuator-Count MEMS DM Systems



PI: Peter Ryan

Boston Micromachines Corporation - Cambridge, MA

Identification and Significance of Innovation

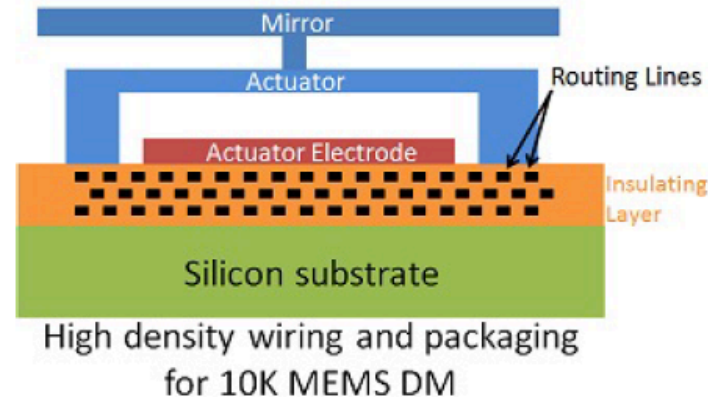
Our proposed innovation is a design and manufacturing approach for **small-stroke, high precision deformable mirrors and associated driving electronics scalable to 10,000 or more actuators**. The proposed design study promises inherent advantages in scalability, yield, and reliability in comparison to current generation MEMS DMs. This innovation addresses a technology gap for next-generation planet finding instruments that was described in NASA's most recent Strategic Plan. NASA needs high actuator count (>10,000) DM systems that can be used in space. Our proposed new design aims to ensure high yield while maintaining the superb optical quality (e.g., flatness and smoothness) needed for adaptive compensation in space coronagraphs. The proposed system architecture is manufacturable using existing fabrication tools and retains proven aspects of microelectromechanical systems (MEMS) for DM production while innovating in areas that have, to-date, limited scalability to higher actuator counts.

Estimated TRL at beginning and end of contract: (Begin: 3 End: 3)

Technical Objectives and Work Plan

The objective in the Phase I project is to complete a design study for an innovative approach to scaling up the heritage BMC MEMS DM technology so that it will be possible to produce high-yield devices and DM systems with 10,000 or more active actuators. To achieve this objective, two key technological challenges must be overcome. Our proposed approach to overcoming these challenges introduces two fundamental changes in the design and manufacturing approaches used to date by BMC for high-actuator count systems: Replacing wire-bond connections with flip-chip bonding and replacing conventional ceramic packages with printed circuit board interfaces. The project duration will be six months, and the project plan will include four distinct tasks.

1. Demonstrate feasibility of flip chip bonding for existing small actuator count BMC DMs
2. MEMS design study for multilayer routing lines
3. Design a multi-level wiring layer 10,000 actuator deformable mirror
4. Model thermal and mechanical behavior of the assembled system



NASA Applications

The following NASA applications apply to all BMC mirrors that benefit from new manufacturing processes described. In the case of space telescopes, mission concepts include the Large UV/Optical/Infrared Surveyor (LUVOIR), Alpha Centauri Exoplanet Satellite (ACESat) and Exoplanetary Circumstellar Environments and Disk Explorer (EXCEDE). For ground-based telescopes, installations include the planned Extremely Large Telescopes: Thirty Meter Telescope (TMT), European Extremely Large Telescope (E-ELT) and the Giant Magellan Telescope (GMT).

Non-NASA Applications

Space surveillance programs funded by Department of Defense administration. Lasercomm systems for long-range secure communication. Also fiber optic communications for use in an optical switching capacity. Microscopy modalities such as multi-photon excitation fluorescence (MPEF), second- and third-harmonic generation (SHG/THG) and localization microscopy techniques. General Beam-Shaping applications.

Firm Contacts

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NON-PROPRIETARY DATA

NASA SBIR/STTR Technologies

S3.04-8513 - AutoNav Mark 4: Autonomous Navigation Software



PI: Christopher Grasso
Blue Sun Enterprise, Inc. - Boulder, CO

Identification and Significance of Innovation

Highly capable onboard autonomous GNC

- spacecraft positioning (abs and rel: helio, planet, small body)
- orbit determination
- target tracking of bodies, apertures, spacecraft, ground-based assets
- trajectory derivation
- low-thrust maneuvering for Solar Electric Propulsion (SEP)
- ephemeris calculations
- pointing

Reduce navigator time and costs, share personnel across missions

Reduce / eliminate Deep Space Network ranging time for spacecraft

Run on any CPU (SPARC, PPC, Intel)

Estimated TRL at beginning and end of contract: (Begin: 2 End: 4)

Technical Objectives and Work Plan

Start: 6/1 End: 12/15

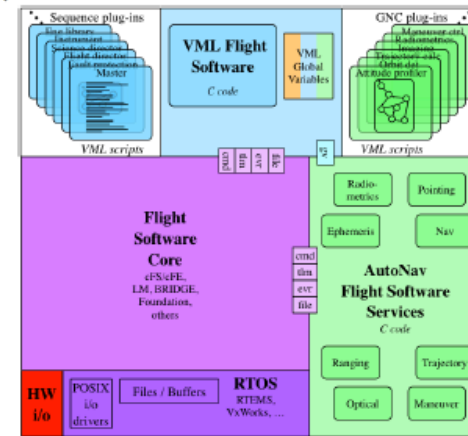
1 TIM: JPL Navigation Section

Work Plan:

- Study AutoNav mark 3 software and tests in detail
- Derive software requirements from existing code, interviews
- Create requirements test matrix
- Create high-level system architecture
- Create functional breakdown

Objectives:

- Characterization of existing AutoNav Mark 3 source code and tests
- AutoNav Mark 4 level-1 requirements
- High-level system architecture and functional breakdown



NASA Applications

- Autonomous navigation, trajectory, ephemeris
- Deployable in C&DH, STRS radio, stand-alone box
- Triangulate on asteroids to reduce DSN ranging
- Low-thrust SEP transfers, circularization
- Autonomous rendezvous for Mars Sample Return
- Human spaceflight autonomous earth-return

Non-NASA Applications

- Autonomous navigation, trajectory
- Launch vehicle and upper stage
- DoD, international missions
- Small commercial and university CubeSats
- Commercial crew ISS intercept, servicing, reentry

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